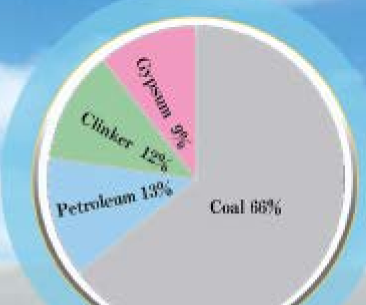
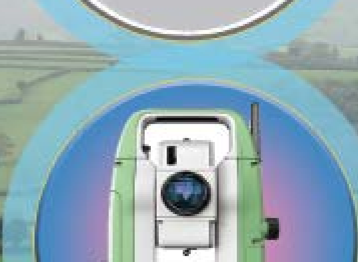
Practical Geography

for Advanced Secondary Schools

Teacher's Guide

Form Five and Six





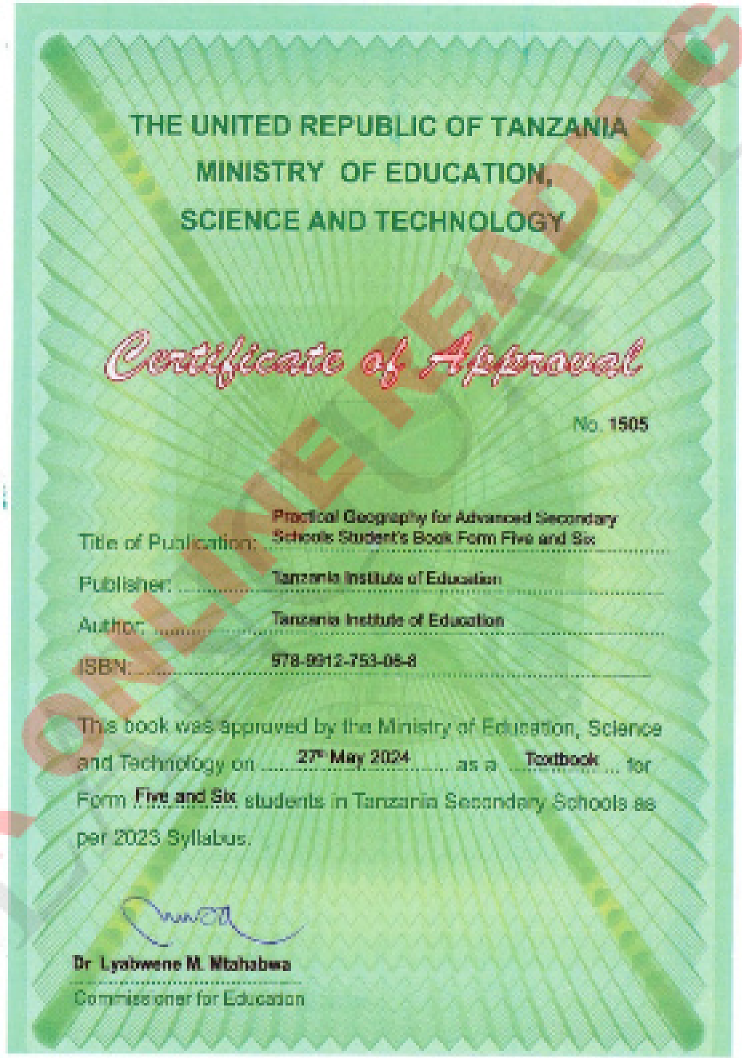
Tanzania Institute of Education

Practical Geography

for Advanced Secondary Schools

Student's Book

Form Five and Six



THE UNITED REPUBLIC OF TANZANIA
MINISTRY OF EDUCATION,
SCIENCE AND TECHNOLOGY

Certificate of Approval

No. 1505

Title of Publication: Practical Geography for Advanced Secondary Schools Student's Book Form Five and Six

Publisher: Tanzania Institute of Education

Author: Tanzania Institute of Education

ISBN: 978-9912-753-06-8

This book was approved by the Ministry of Education, Science and Technology on 27th May 2024 as a Textbook for Form Five and Six students in Tanzania Secondary Schools as per 2023 Syllabus.

Dr. Lyabwene M. Mtahabwa
Commissioner for Education

Tanzania Institute of Education

First edition 2022

Revised edition 2024

ISBN: 978-9912-753-06-8

Tanzania Institute of Education
Mikocheni Area
Ali Hassan Mwinyi Road
P. O. Box 35094
14112 Dar es Salaam

Mobile numbers: +255 735 041 168/ +255 735 041 170
E-mail: director.general@tie.go.tz
Website: www.tie.go.tz

Table of Contents

Acronyms and abbreviations

Gb	Giga bite
GIS	Geographic Information System
GWh	Giga Watt per hour
JNIA	Julius Nyerere International Airport
KIA	Kilimanjaro International Airport
LEO	Low Earth Orbiting
TMA	Tanzania Meteorological Authority
TANESCO	Tanzania Electric Supply Company
TPDC	Tanzania Petroleum Development Cooperation

Acknowledgements

The Tanzania Institute of Education (TIE) would like to acknowledge the contributions of all the organisations and individuals who participated in designing and developing this textbook. In particular, TIE wishes to thank the University of Dar es salaam (UDSM) and the University of Dodoma (UDOM), Zanzibar Examination Council (ZEC), School Quality Assurance (SQA) Department, teachers' colleges and secondary schools. Besides, the following individuals are acknowledged:

Writers:	Dr Fredy S. Mswima Ms Beatrice S. Rulenguka, Ms Neema A. Kashindye, Mr Hemed K. Mdee.
Editors:	Dr Julius Mngumi, Mr Anton Nzali , Dr Festo J. Ndumbaro, Dr Barnabas M. Msongaleli, Dr Julius E. Frank, Mr Frank Mahuve, Mr Daniel A. Mwalutolo, Mr Michael N. Sichundwe, Mr Iddi A. Moh'd and Mr Isack J. Sondoma.
Designer:	Mr Anton Asukile
Photographer:	Mr Chrisant A. Ignas
Illustrators:	Mr Fikiri A. Msimbe, Ms Rehema Maganga and Mr Godlove Kyando
Coordinator:	Ms Neema A. Kashindye

TIE also appreciates the contributions from the secondary school teachers and students who participated in the trial phase of the manuscript. Likewise, the Institute would like to thank the Government of the United Republic of Tanzania for financing the writing and printing of this textbook.

Dr Aneth A. Komba
Director General
Tanzania Institute of Education

Preface

This textbook, *Practical Geography for Secondary Schools*, is written specifically for Form Five and Six students in the United Republic of Tanzania. The book is prepared in accordance with the 2023 Geography Syllabus for Advanced level Secondary Education, Form V-VI, issued by the Ministry of Education, Science and Technology (MoEST). It is a revised edition of Practical Geography for Advanced Secondary Schools Student's Book for Form Five and Six that was published in 2022 in accordance with the 2010 syllabus issued by the then Ministry of Education and Vocational Training (MoEVT).

The Textbook consists of five (5) chapters, namely Land surveying, Geographical Research, Geographical data analysis and interpretation, Techniques of photograph interpretation and Maps and map interpretation. In addition, each chapter contains activities, scenarios, projects, and exercises. You are encouraged to do all the activities, projects, tasks and questions. You are also required to prepare a portfolio for keeping records of activities performed in different lessons. This will enhance your understanding and development of the intended competences

Additional learning resources are available in the TIE e-Library *https://ol.tie.go.tz* or *ol.tie.go.tz*

Tanzania Institute of Education

Chapter One

Land surveying

Introduction

Land surveying has remained important discipline throughout human life. Land surveying is used in determining site locations, demarcating boundaries of land parcels, setting out engineering structures, and map making for various land uses. In this chapter you will learn about the concept of land surveying, procedures for land surveying, classification of land surveying, prismatic compass survey, plane table surveying and levelling survey. The competences developed will enable you to determine locations of points using compass surveying, plane table surveying and levelling survey.

Think about

Determining areas and distances of a place on the Earth's surface

Concept of land surveying

Activity 1.1

Search from various sources about land surveying activities then write short notes on their significance in our lives.

Since ancient time, land surveying has been used to set important marks on the land. The established marks, also referred to as control points, were used to establish positions of features on the land. For instance, in ancient Egypt, surveyors called *rope stretchers* used the control points and simple geometry to re-establish marks of boundaries swept-off by annual floods of the Nile River. The name rope stretchers originated from a marked rope which was their principal tool of survey, and today's chain survey originated from this marked rope surveying. It was associated with making linear measurement between the established points or stations. In his work, "*The Sea Island Mathematical Manual*" published in 263 AD by ancient Chinese mathematician, Liuhui, described ways of measuring distant objects. The work of Liuhui founded the growth of survey which was latter recognized by Romans as a profession.

Thus, land surveying or geomatics as a profession can be defined as the science, art, and technology of determining the relative positions of points or features above, on, or beneath the earth's surface. The determination of such relative position involves measurements of distances and angles, which results to graphical or numerical presentation of measured values.

Land surveying supplies data by which accurate space-based plans and maps of the earth's surface or part are made. Land survey can aid proper land management and administration in ecumene. The planning of proper layout of streets and water supplying network, division of arable land for farming and other services are significant contributions of land survey. Land surveying is further applied in planning, designing and setting out of engineering structures like large buildings, dams, roads, railways, bridges and road interchanges.

Influence of technological development on land surveying

Land survey is part and parcel of human life and his development. Land surveying aims at establishing boundaries, creating navigation maps, and creating plans and maps for different land uses. To accomplish such tasks, humans have been innovating tools for taking linear, angular, and area measurements.

While the purpose of surveying has remained the same since ancient Egyptian survey (3000 BC) (Figure 1.1), surveying instruments have evolved drastically with technological development.

Figure 1.1: *Ancient Egyptian survey*

The linear measurement instruments have evolved from chains and Gunter's steel band through steel band and metal tapes to Electronic Distance Measurement (EDM) instruments (Figure 1.2). Subsequently, the Global Positioning Systems (GPS) devices have improved efficiency and greater accuracy of measurement than any other preceding instruments.

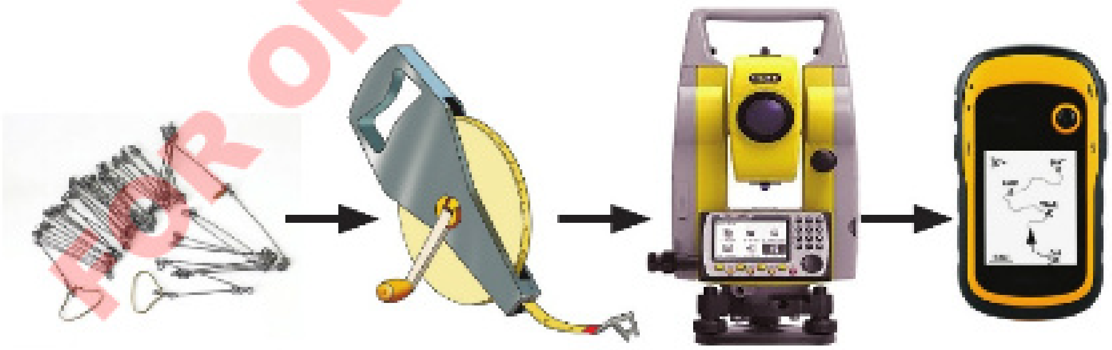


Figure 1.2: *Evolution of distance measuring instruments*

Just as it was for linear measurements, instruments for angular measurements have also evolved significantly from the Egyptian Groma (which has been perpetuated by the cross-staff and its successor, the optical square) through dioptra to the compass like-instruments called *astrolabe*. The dioptra and astrolabe were followed by sextants, which are more professional and accurate. Evolution of modern angular measurements began with compasses that were followed by Transit, Theodolites and Total stations (Figure 1.3). A total station is a multipurpose surveying instrument that combines the functions of Transit level or Theodolite and electronic distance measurement (EDM) into a single instrument.

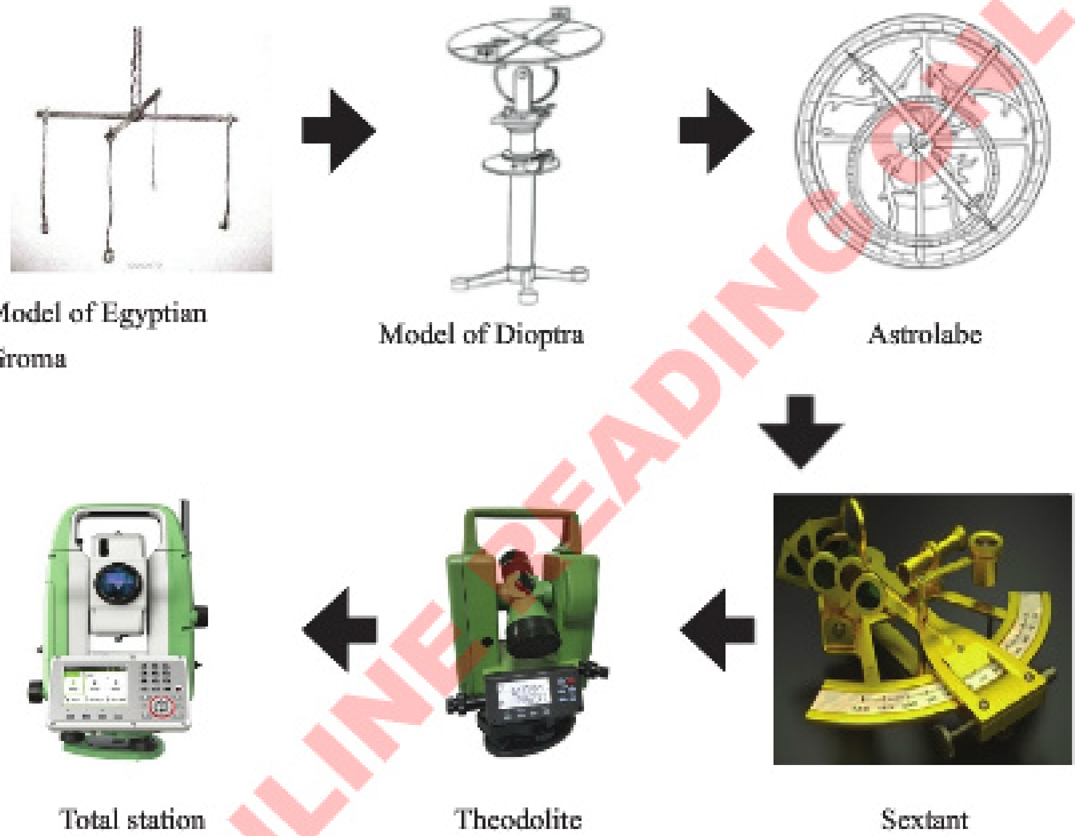


Figure 1.3: *Evolution of angular measuring instruments*

Morphologically, there is only a slight difference between Theodolite and Total station. The main difference is on their function and applications. Total station is used to measure both angles and distances while Theodolite is used to measure angles only. Modern angular measurement instruments use principles of electronics to calculate angles and distances.

However, in this chapter, you will learn basic surveying techniques using basic instruments to understand principles of surveying, which also apply when using modern instruments.

Procedures for land surveying

Most of land surveying involves three important procedures: *reconnaissance*, *fieldwork* and *office work*. Reconnaissance is the first process in land surveying in which the surveyor gets a general view of the area to be surveyed. In this step, a surveyor gathers information related to the area to be surveyed for familiarisation with its landscape and gets an overview of what may be required before the commencement of a fieldwork. This stage helps the surveyor in planning for the execution of the survey project, particularly in identifying appropriate survey methods, instruments, required manpower, preparation of budget and time schedule.

Fieldwork is the actual execution of survey work which involves observations and measurements of distances and angles, recording of measurements in a field notebook, preparing field sketches and performing simple calculations.

The office work is the last process which is carried out in the office and involves analysis of survey data, reduction of levels, calculation of coordinates, preparation of plans, maps and other graphics, as well as calculation of areas and volumes of Earth quantities.

Classification of land surveying

Although land surveying is usually classified on the basis of a multitude of criteria, geodetic and plane survey make the general classification in the discipline. The two classes are types of surveys with their differences rooting on the key assumptions they hold. *Geodetic survey* assumes the Earth as a curved surface (ellipsoid) and that any computation must consider the ellipsoidal nature of the surface, while the *plane surveys* assume the earth's surface as flat. However, the terms plane surveys and plane table surveying should be treated differently. The former is a type of surveys, the latter represents a technique of plane surveying. Geodetic methods are employed in surveying relatively large land masses, usually covering over 250 square kilometres at national and continental scale, and widely spaced monuments or features. Plane surveys, on the other hand, are used in mapping areas covering less than 250 square kilometres. Contrary to geodetic survey which treats all lines joining stations as arcs, plane surveys consider all lines joining two or more points as straight lines.

A demand of high accurate data in geodetic surveys requires instruments of high precision, accuracy and economy than those employed in plane surveys. Prior to 1970, accurate observation of angles and distances to collect spatial data in geodetic surveys was difficult and painstaking. Angles were measured using precise ground-based Theodolites while distances were measured using special tapes made from metal with low coefficient of thermal expansion. Although these instruments are still used for angles and distances measurement to date, satellite positioning has almost replaced other instruments in geodetic survey. The entire scope of satellite systems used in positioning is referred to as *global navigation satellite systems* (GNSS) (Figure 1.4). The GNSS operation relies upon signals from satellite.

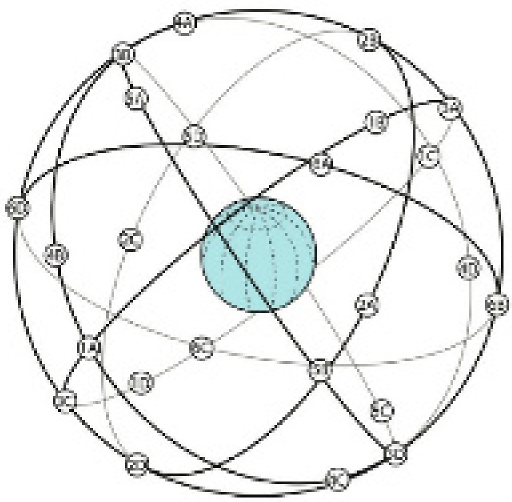


Figure 1.4: *Global navigation satellite systems*

Receivers that use multiple satellite systems like GPS, Global Navigation Satellite System (GLONASS), Galileo, and BeiDou are known as *Global Navigation Satellites System* (GNSS) receivers (Figure 1.5). GNSS receivers use satellites as their reference points. The GPS, GLONASS, Galileo and BeiDou positioning systems are satellite constellations managed by different states or countries. The systems provide precise timing and positioning anywhere on the Earth with high reliability and low cost. The systems operate during day and night, rain or sunshine, and do not require cleared lines of sight between survey stations. However, GNSS receivers must be visible to satellite for signal transmission. Currently, GNSS receivers are used in all forms of surveying including hydrographic, construction and boundary surveying.

Figure 1.5: *Global navigation satellite systems receiver*

Although GPS and GNSS are treated synonymously and used interchangeably by many surveyors, the terms are distinctive and each has its own unique meaning. The term GNSS is an inclusive term that describes satellite navigation systems from any country or region while GPS refers specifically to the Navigation Satellite Time and Ranging (NAVSTAR) which is the satellite navigation system of the United States. The most common GNSS are GPS (United States), - GLONASS (Russia), Galileo (European Union), BeiDou (China), Quasi - Zenith Satellite System - QZSS (Japan) and Indian Regional Navigation Satellite System (IRNSS).

Specialised types of survey

The existence of many types of surveys, named after principal devices, objective and surface surveyed, among other criteria, implies existence of a specialised type of survey in each area. There are many specialised types of surveys including chain or tape survey, compass survey, plane table survey, levelling survey, hydrographic survey, topographic survey, control survey, cadastral survey, mine survey, tacheometric survey, aerial survey, photogrammetric survey and satellite survey. However, in this chapter, the emphasis is put on compass surveying, plane table surveying and levelling surveying.

Compass surveying

One way of identifying the location of the intended objects in relation to other nearby permanent objects is through compass survey. A detail in compass survey can be positioned by *traverse, intersection* and *resection* methods.

The compass surveying involves fixing of an object's position in the field by measuring the angles of bearings between the line of magnetic North (0°) and the line of sight to the object (Figure 1.6).

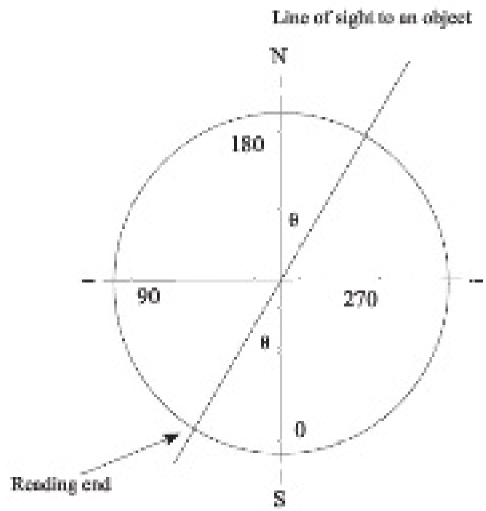


Figure 1.6: *Measuring angle by compass*

Compass surveying is commonly employed when the land area to be surveyed is comparatively larger than the area covered in chain surveying. Compared to chain, compass surveying is suitable for rough landscapes. Compasses for land surveying originated from a Chinese 'iron-attracting mineral (lodestone) and have been in use since 400 years BC (Figure 1.7). Ancient Chinese suspended the lodestone with their hands or on boats and other navigation facilities to help them point 'South'. The use of lodestone as a compass to point to the south gave birth to its names such as "*South-governor*" and "*South-pointing-fish*". Swinging of the lodestone, the south governor, or the south-pointing fish as they called it to point the south, then became the origin of the today's compass used in survey.

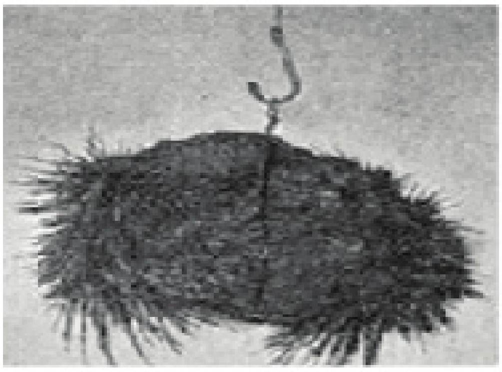


Figure 1.7: *Lodestone*

Types of compass

There are two major types of compass surveys which are the prismatic and surveyor's compasses. The compasses are differentiated by key features including; their body size, the bearing system they use to designate readings, and their mode of formation.

Surveyor's compass

A surveyor's compass is an old form of compass used by surveyors which is similar to the prismatic compass but with few modifications. It is used to determine the magnetic bearing of a given line. The instrument has commonly been referred to as the *Circumferentor*. Surveyor's compass is larger and more accurate than prismatic compasses and designated to read bearings in quadrant bearing system (QBS) as shown in Figure 1.8.

Figure 1.8: *Surveyor's compass*

Prismatic compass

This is a non-magnetic metal case with a graduated ring and glass top used for determining angles, bearings and direction to objects of surveyor's interest. It is a small, hand-held device in a circular box of about 100 mm in diameter used in fixing objects in the field and from which the angle of bearing is measured between the line of magnetic north and the line of sight to the object. This type of compass is usually used for surveying works that do not require very high accuracy. For example, preliminary survey for minerals exploration.

The morphology of prismatic compass can be identified by its elements. They include its cylindrical metal box, lifting pin and lifting lever, magnetic needle, graduated circle or ring, prism, object vane, eye vane, glass cover, sunglasses, reflecting mirror, and spring brake pin. Prismatic compass is a cylindrical metal box with a graduated ring supported by pivot at its centre. Provided just below the sight vane are the lifting pin and lifting lever, which assists in pressing the lifting pin when the sight vane is folded. The lifting pin, with the help of the lifting lever, lifts the magnetic needle out of the pivot point to prevent damage to the pivot head. The magnetic needle of a prismatic compass is a core part of the instrument. It is attached to the graduated aluminium ring marked in degrees from 0° to 360° and measures bearings of lines from the magnetic meridian. The needle that always points towards the north-south pole at its two ends when freely suspended (Figure 1.9) measures angles to the objects.

Figure 1.9: *Prismatic compass*

Another important element in the prismatic compass is the prism. This is why the technique is termed as prismatic compass. The prism assists surveyors to read graduations on the graduated compass ring and to take the exact degree values. The prism is made up of a hole called prism hole. The prism hole is protected from dust and moisture by prism cap. The eye vane provided with an eye hole and the top glass to protect the ring, complements the operations of other compass parts such as sun glasses, reflecting mirror and spring brake. Prismatic compass is designed to read bearing in whole circle bearing (WCB) system.

Designation of compass bearing

There are two types of bearing designations. They include Quadrant Bearing System (QBS) and Whole Circle Bearing system (WCB). In QBS, the bearing of survey lines is measured from either the north line or south line, depending on whichever is nearer to the given survey line. The bearing readings can be done clockwise or anti-clockwise. Bearings in QBS range from 0° to 90°. The NORTH and SOUTH poles are designated by 0° while the WEST and EAST ones are designated by 90°. In QBS, the angular value is preceded by prefix N or S and followed by the suffix E or W based on its quadrant. For example, an angle of 45° magnitude measured from North towards East, which is in first quadrant is written as N 45° E. In WCB designation, bearings are measured clockwise from North direction and range from 0° to 360°. Bearings in QBS and WCB are also referred to as bearing and azimuth, respectively.

Compass survey by traverse method

The term traverse is used to refer to a series of connected lines of known lengths related to one another by known angles. There are two types of traverses namely, the *open traverse* and *closed traverse*. When a series of connected lines forms a closed circuit, it is called a 'closed traverse'. In closed traverse, reading and taking of bearings or azimuth starts and ends at the same station as shown in Figure 1.10(a). On the contrary, when the survey lines start from one point and end at another point which is not the starting point as shown in Figure 1.10(b) we get what is known as open traverse.

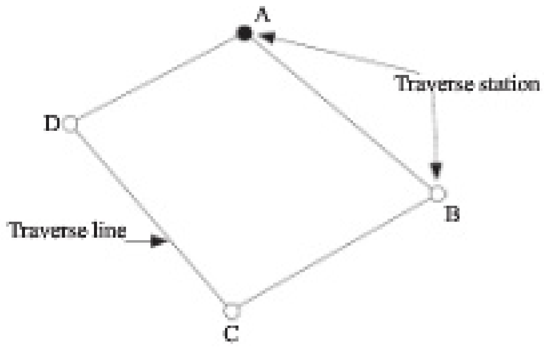


Figure 1.10 (a): *Closed traverse*

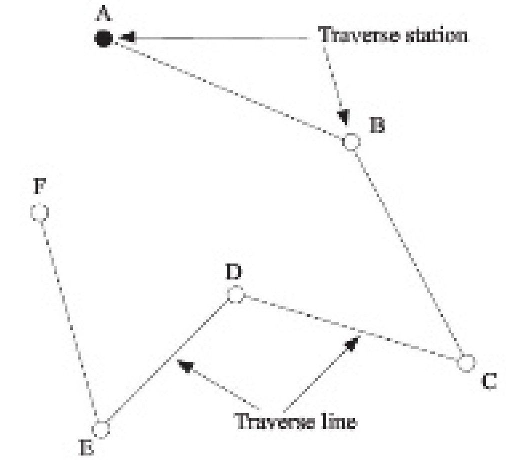


Figure 1.10 (b): *Open traverse*

Reference meridians

In this case, the bearing is a horizontal angle which is made with reference to a particular line called meridian to the line of sight. Basing on the meridian, the surveyor chooses the reference. There are four types of meridians: the true meridian, magnetic reference meridian, grid meridian and arbitrary meridians. The true bearing of a line is the horizontal angle between the true meridian and the line of sight. The true reference meridian is defined as the line along the earth's surface connecting the North and South poles. The true North is also called geodetic north. The true meridian or North as frequently referred to by geographers, is different from the magnetic north which is the direction pointed by the compass, and it is different from the grid north which is in the direction along the grid lines towards the north. The true bearing is measured from the true North in the clockwise direction (Figure 1.11).

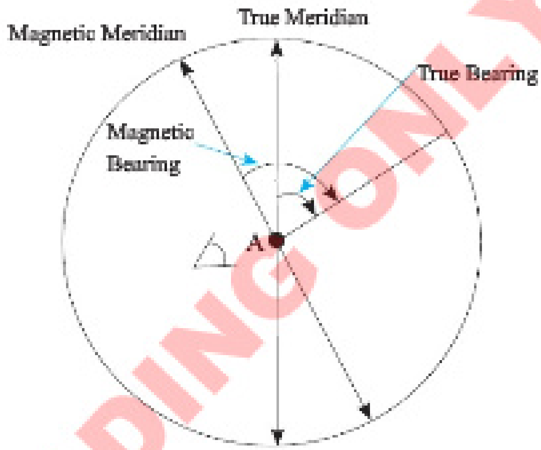


Figure 1.11: *Traverse magnetic bearings*

The magnetic bearing on the other hand refers to the horizontal angle which the line of sight makes with the magnetic north as shown in Figure 1.11. It is the direction which is pointed by the compass needle in response to the earth's magnetic field. The deviation between the true north and the magnetic north varies from place to place as the earth's magnetic poles are not fixed with respect to its axis. The earth's magnetic poles are not aligned to the actual geographic north and south poles. Instead, the magnetic South Pole is in Canada which is in the north while the magnetic North Pole lies in Antarctica which is in the south. The magnetic poles are inclined by about 10 degrees to the earth's rotational axis as shown in Figure 1.12.

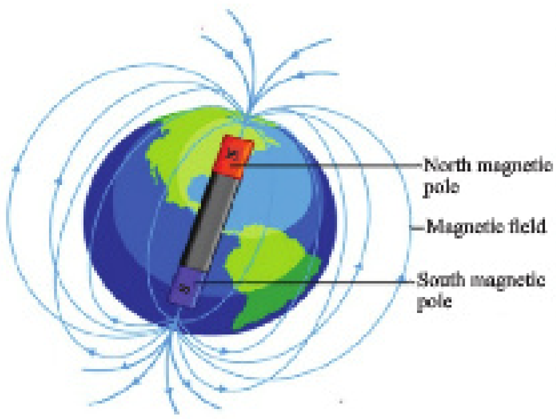


Figure 1.12: *Distribution of earth's magnetism*

Grid bearing means horizontal angle measures from the grid line to the line of site. Grid meridian is a line parallel to the central true meridian for a specific area covered by plane coordinate system. An arbitrary bearing is the horizontal angle between the line of sight AB and any established arbitrary meridian. An arbitrary meridian serves as a temporary north whose magnetic or true bearing could latter be determined. The meridians, also termed as Norths, that is, *Magnetic North (MN)*, *True North*, *Arbitrary North* and *Grid North*, are major reference points in compass surveying.

Back and forward bearing

In prismatic compass survey, a survey line can be defined by two bearings: the forward bearing which is taken from one station to the other in the direction of a survey and the back bearing which is taken in the opposite direction of the survey direction. Both bearings are expressed in whole circle bearing (WCB). The forward and back bearing in WCB differs by 180°. That is, the bearing (α) of the line *AB* in the survey direction from *A* to *B* is a forward bearing, whereas the bearing (β) of the line *AB* opposite the survey direction, that is, from B to A, is a back bearing (β) (Figure 1.13).

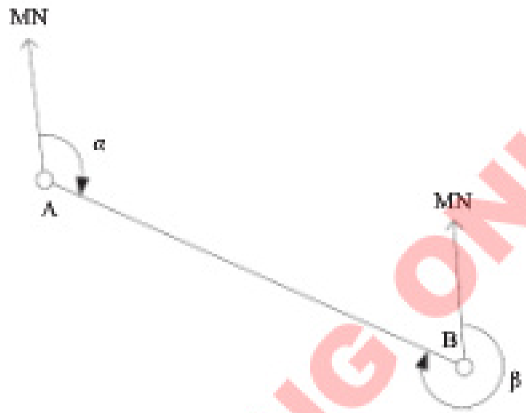


Figure 1.13: *Forward (α) and back (β)bearing*

This means, if the forward bearing is greater than 180°, then subtract 180° to get the back bearing, and when the forward bearing (FB) is less than 180°, add 180° to get the back bearing (BB). However, it must be noted that, this can only be meaningful when checking the accuracy of the data collected from the field. In the field, the FB and BB must be measured for each survey line.

Thus, the calculation for FB and BB can be summarised by the formula below:

$FB = BB \pm 180^0$

and $BB = FB \pm 180^0$

Field procedures for compass survey by traverse method

Prismatic compass surveying has important preliminary procedures to be considered before the actual field practice is carried out. Any attempt to ignore them can lead to erroneous reading of the bearings. Therefore, adjustment of a prismatic compass before conducting any activity is necessary. Two types of adjustments can be done: temporary and permanent adjustments.

Temporary adjustment is done during field work at every station while permanent adjustment is done occasionally, usually at the factory to ensure the compass is in good working condition. It involves adjusting the plate level, sight vane, magnetic needle and pivot.

The following field procedures are followed in compass surveying:

1. Prepare all necessary equipment for the prismatic compass survey. Important equipment includes: Prismatic compass, chain or tape, ranging rod or poles, tripod stand, field notebook and other drawing materials like rubber and pencils. Do not dress or carry metal material during compass surveying. Iron materials like a bunch of keys, ear and finger rings, watch, metal frame or rimmed eyes glasses can interfere with the compass readings and consequently lead to incorrect readings.
2. Establish stations through which your traverse will be carried out. For example, in Figure 1.14, stations A, B, C, D, E and F are established for a six-sided farm/piece of land.

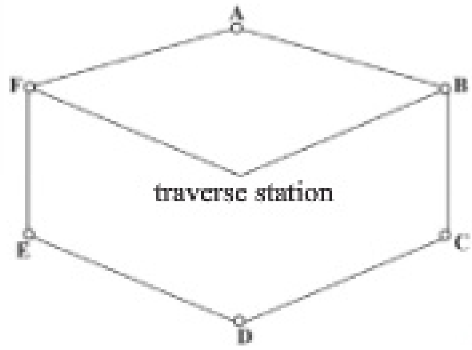


Figure 1.14: *Corner points of a farm to be surveyed*

3. Set a compass over station **A** and perform temporary adjustment. Temporary adjustments include the following operations:

(i) *Cantering the compass:* this is the setting of a compass at its centre over the ground station mark. It involves making the pivot exactly vertical over the ground station mark. A station mark can be a boundary beacon or a brick established for that purpose. Cantering is done by adjusting the legs of the tripod stand. To ensure the compass is on top of the starting point, a plumb bob is hung from the centre of the circular box, to define a vertical line. If no plumb bob is provided, the cantering may be judged by dropping a small pebble freely from the centre of the bottom of the circular box. If the compass is centred perfectly, the pebble will fall exactly over the ground station mark.

(ii) *Levelling:* is the other adjustment which involves the setting of the compass horizontally such that its graduated ring swings freely. Levelling of a compass can be done by the level specially made for that purpose or estimated by eye. Generally, the compass is provided with a *ball and socket* arrangement attached to the tripod for achieving quick levelling of the instrument. In the surveyor's compass, two plate levels at right angles to each other, are sometimes provided. The ball and socket arrangement is adjusted till the two bubbles remain central in both plate levels.

(iii) *Focusing the prism:* The process of moving up or down the prism for obtaining the figures and graduations sharply and clearly, is called *focusing the prism.* This adjustment is for prismatic compass only.

After temporary adjustment of A, sketch a forward bearing to B. Then, shift the instrument to station B, perform temporary adjustment and read the back bearing to A to check for angular error. Finally, measure the distance between station A and B and record all measurements in the field notebook.

4. Continue taking forward and back bearings and measuring distances for all remaining traverse stations as shown in Figure 1.15.

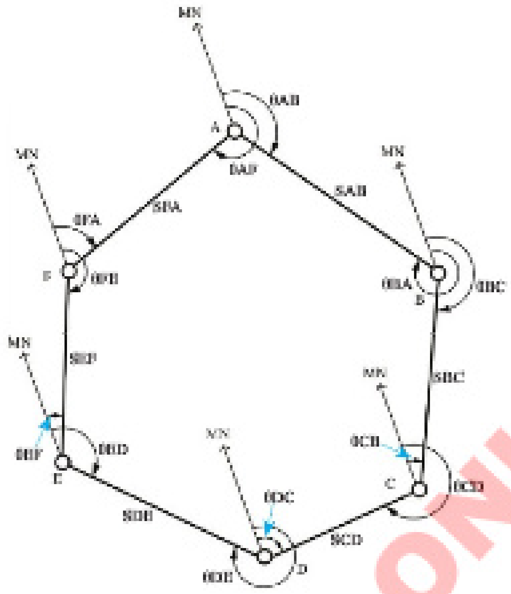


Figure 1.15: *Clockwise reading of forward (blue arrows) and back bearing (black arrows)*

5. Correct the observed field data for any error. Correction for the error can be done in two ways: graphically and mathematically. However, in this chapter, the focus will be on the graphical method. In the graphical method, the data should be plotted and if there are some errors, the traverse will not close. This is as shown in Figure 1.16, the last survey line will not join the station where the survey started.

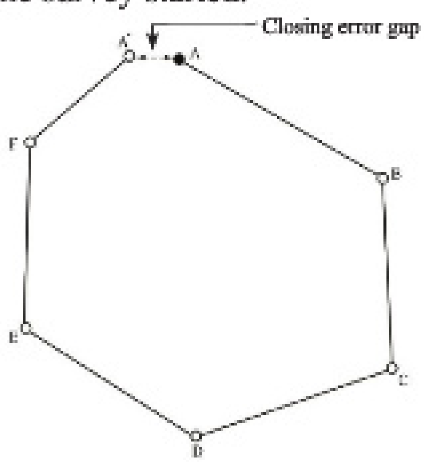


Figure 1.16: *Traverse closing error gap between A' and A*

Graphical correction of traverse closing error

Commonly, the north end of a freely suspended magnetic needle of the compass always points to the magnetic north, if it is not influenced by any other external forces except the earth's magnetic field. Sometimes, the magnetic needle gets deflected from its normal position, if the compass survey is carried near magnetic rocks, iron ores, cables carrying current or iron electric poles. Those forces disturbing the compass needle are called '*local attraction*'. Prismatic compass is therefore not reliable in areas with these characteristics, unless they are checked against each station and eliminated.

The presence of local attraction at any station may be detected by calculating forward and back bearings of the line to see if the difference between them is 180°. If checked and found that the difference between forward and back bearings is 180°, then both end stations are free from local attraction. If not, the discrepancy maybe due to:

(a) An error in the observation of either forward or back bearings or both: For example, not holding the compass steadily at 180° when taking bearings.

(b) Presence of local attraction at either station or around.

(c) Presence of local attraction at both stations.

(d) Slugging pivot or needle.

Local attraction at any station affects all the magnetic bearings by an equal amount and therefore, the included angles deduced from the affected bearings are always correct. In case the forward and back bearings of lines of traverse differ by the permissible error of reading, the mean value of the bearings of the line least affected may be accepted. The correction to other stations may be made according to the following methods: graphical method based on local attraction and graphical method based on Bowditch rule.

Graphical method based on local attraction

The graphical method based on local attraction involves calculation of error due to local attraction at each station. The procedures for correcting errors due to local attraction are illustrated based on the traverse data presented in Table 1.1.

Table 1.1: *Errors due to local attraction in open traverse ABCDE*

Station	Length (m)	Observed FB	Observed BB	Calculated FB	Error
AB	30	45°	226°	46°	+1°
BC	55	135°	316°	136°	+1°
CD	50	90°	270°	90°	0
DE	75	225°	45°	225°	0

To correct errors in the data presented in Table 1.1, follow the following steps.

1. Plot a traverse framework as shown in Figure 1.17 from uncorrected data presented in Table 1.1.

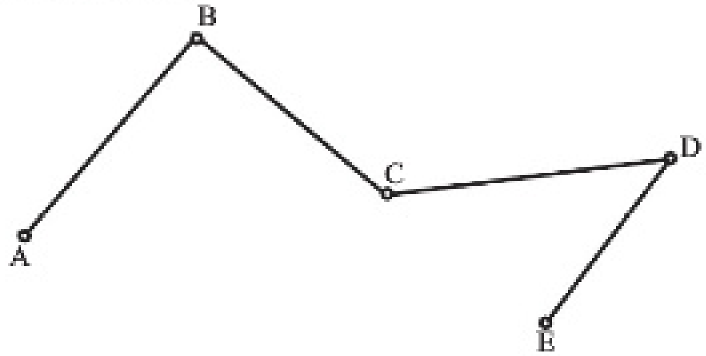


Figure 1.17: *Uncorrected traverse ABCDE*

2. Correct the forward and back bearings observed in traverse ABCDE as shown in Table 1.2.

In correcting the data provided in Table 1.1, use the formula FB = BB ± 180° to check for bearing error in each line. For example, in line AB, BB −180° = 226° −180° = 46° which is greater than the measured FB by 1°. Thus, 1° is the bearing error due to local attraction in line AB. Continue determining errors in the remaining lines. Then, choose a leg not affected or least affected and investigate from there a leg or legs which are affected by local attraction causing the discrepancy. Thereafter, correct each affected leg by adding or subtracting the error. If the observed bearing of a line is greater than the calculated bearing, the error is subtracted and vice versa.

In this example, the difference between the forward and back bearings for lines CD and DE is 0, which means lines CD and DE are not affected by local attraction. Thus, the correction is done for forward and back bearing observed at stations A and B, respectively. Since point C is free from local attraction, errors in line BC are due to local attraction at point B.

Table 1.2: *Corrected forward and back bearing in traverse ABCDE*

Line	Length (m)	Observe bearing		Error	Corrected bearings	
		FB	BB		FB	BB
AB	30	45°	226°	+1°	46°	226°
BC	55	135°	316°	+1°	136°	316°
CD	50	90°	270°	0°	90°	270°
DE	75	225°	45°	0°	225°	45°

3. Then on the first plot of uncorrected angle, plot the traverse using the corrected bearing and observed distance from Table 1.2 using a protractor and a ruler. For example, line ‘bc’ is drawn from point C using corrected back bearing

and the length of line BC. Line 'ab' is drawn from point B using the corrected back bearing and length of line AB. Thus, the correct plot of the traverse is the one presented with lower case letters from 'a' to 'e'. Lines 'cd' and 'de' coincide with lines CD and DE, respectively, as points C, D and E in Figure 1.18 are free from local attraction.

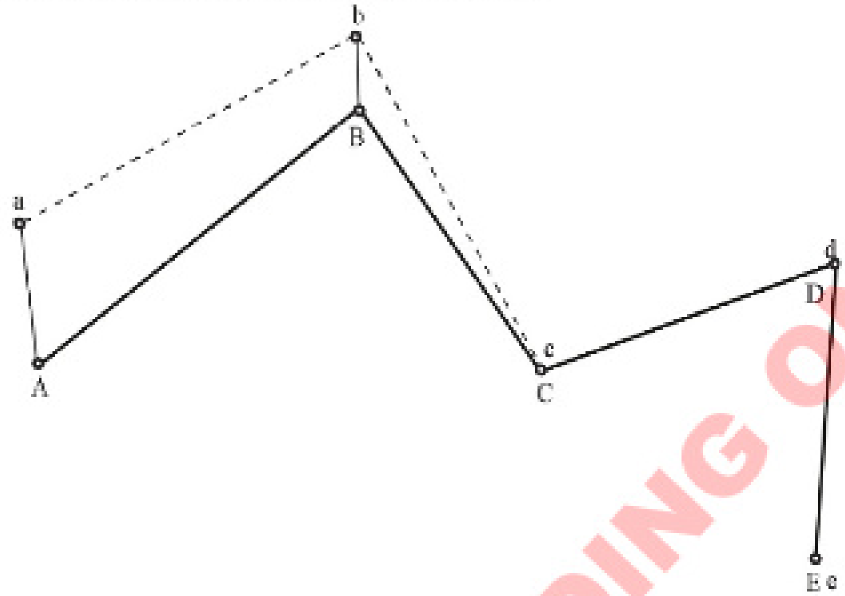


Figure 1.18: *Error correction in open traverse ABCDE based on local attraction*

Activity 1.2

Choose a segment of road not longer than 500 m, then;

(a) Mark each point where the road changes direction.

(b) Reform compass traverse along the marked stations and correct for errors in forward and back bearings.

Graphical method based on Bowditch rule

While the graphical method by local attraction is applicable to both open and closed traverses, the graphical methods based on Bowditch rule is limited to only closed traverse, at the same level as graphical method by local attraction. Four procedures for graphical method based on Bowditch method are illustrated using a closed traverse ABCDEA′ plotted in Figure 1.19, using observed distances and angles.

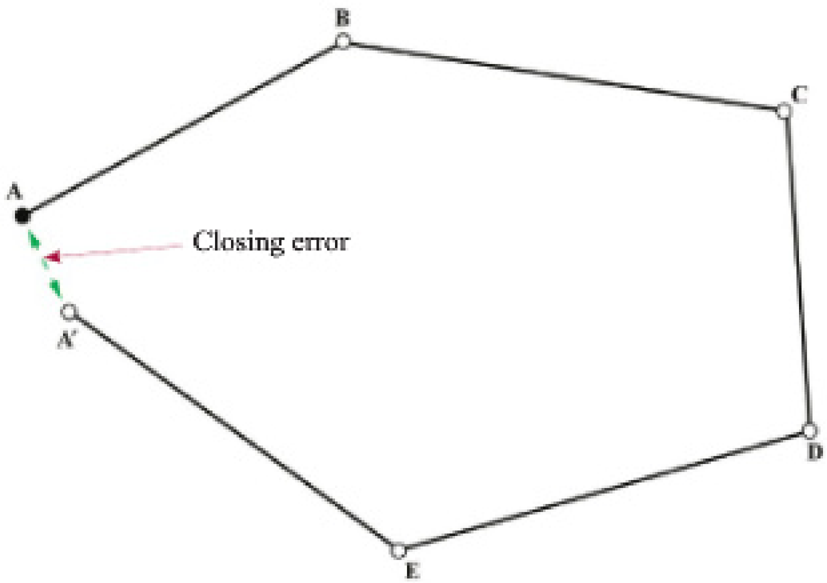


Figure 1.19: *Closing error in traverse ABCDEA′*

1. First measure the misclosure of a traverse by ruler and record. Let's assume the gap is 1.5 cm.
2. Draw a horizontal line (AA') of a length, which equals to the total length of the traverse and mark the position of traverse stations B, C, D, E, A' to scale. Assuming the length of line AB = 40 m, BC = 60 m, CD = 50 m DE = 60 m and EA = 30 m, at a scale of 1:10, the position of stations B, C, D, E, and A' are at 4 cm, 10 cm, 15 cm, 21 cm, and 23 cm from station A, respectively as shown in Figure 1.20.
3. At point A' on the horizontal line draw a vertical line to point 'a' at a distance which equals the measured misclosure, the 1.5 cm to a scale used to plot the uncorrected traverse in Figure 1.19, then draw a line connecting station A on horizontal line AA' and on the vertical line $A'a$. At stations B, C, D, and E, draw vertical lines connecting points b, c, d, and e on line Aa, respectively as shown in Figure 1.20.

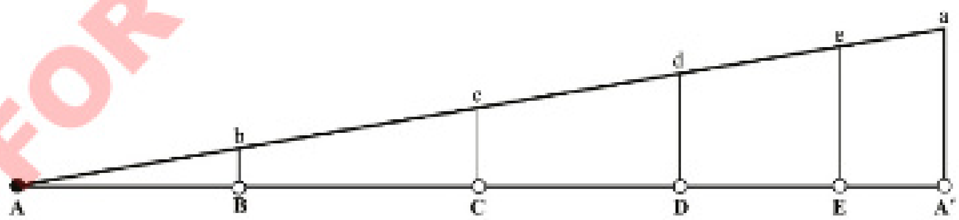


Figure 1.20: *Horizontal line AA' and vertical lines Bb, Cc, Dd, Ee and A'a*

4. Measure the lengths of vertical lines Aa, Bb, Cc, Dd and Ee. After that, on a plotted uncorrected traverse draw a line parallel to line A'a at station B and mark the position of station 'b' along that line. Do the same at stations C, D, and E. Finally, draw a dotted line connecting points A, b, c, d, e and A as shown in Figure 1.21 to show the corrected traverse.

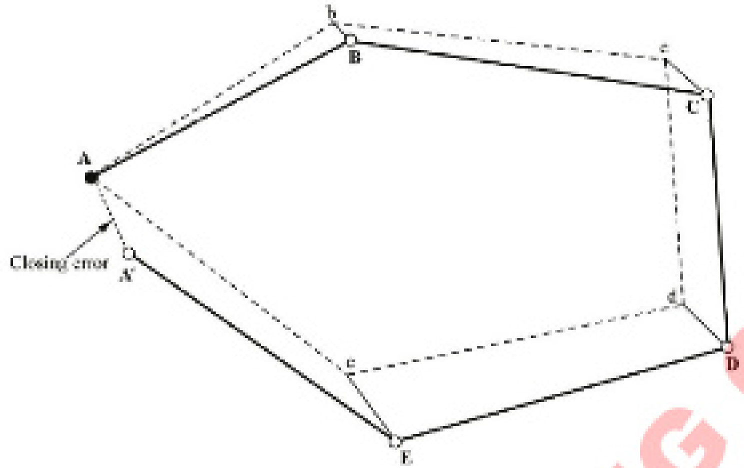


Figure 1.21: *Original traverse ABCDA' and corrected traverse A b c d e A*

Compass survey by intersection method

In intersection method, the point where two lines meet is determined. Thus, intersection is a method of fixing the position of an object relative to two or more points of known positions. It is a method that locate points of intersection by taking forward bearing from two or more fixed points. The procedure, followed in intersection methods are as follows:

1. From two known points, say C and D, for instance, take forward bearing to point X that you want to locate on a map (Figure 1.22).

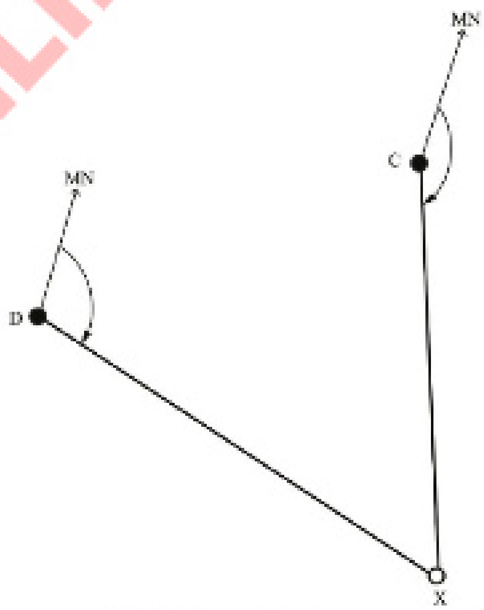


Figure 1.22: *Fixing objects by intersection*

2. Check the accuracy of the forward bearing from points C and D to point X by taking forward and back bearing of line CD;
3. Lastly, convert all magnetic bearings to true bearing; and
4. On a map, draw a line parallel to true north at point C and D. Then, using a protractor mark the direction (bearing) of lines CX and DX, and extend these lines until they cross to define the position of point X.

Compass survey by resection method

Resection differs from intersection since instead of setting the compass at known points, you set it at the unknown points, for example station Y. Thus, forward bearings are read from station Y to points or features of known map locations as shown in Figure 1.23.

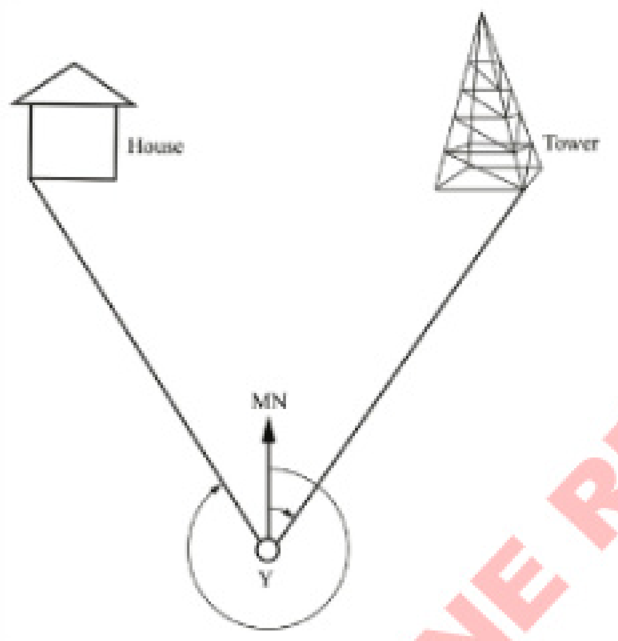


Figure 1.23: *Fixing objects by resection method*

Procedures for compass surveying by resection methods are the following:

1. Set a compass at unknown station Y and perform all temporary adjustment;
2. Take forward bearings from point Y to two or more known permanent points. Do not record a car or animal as an object to fix your point. Use permanent objects like tower and house. Animals and cars are mobile and therefore cannot be shown on the map;
3. Then convert all magnetic bearings to the fixed point you have chosen into true bearings using the formula presented below;

   TB = MB ± Declination
   where; TB is true bearing
   MB is magnetic bearing

   The magnitude of declination is subtracted when it is western and added when it is easten.
4. To fix point Y on a map, calculate the back bearings from the forward bearing obtained in step (2) above. Then, on a map where the location of a house and tower in Figure 1.23, draw a fine pencil line parallel to the true north at the chosen objects, in this case, a house and a tower; and

5. Measure the respective true back bearing calculated in step (3) at the two chosen objects and extend these lines until they cross each other to mark the position of point Y.

Plotting of prismatic compass field data

Field surveying of all types aims at extracting important information that can be communicated in a manner that every user can understand. Information obtained in compass surveying is recorded in field notebooks. Notebooks contain information which is not easy to be understood by common users. They are short hand, sometimes roughly written and peculiar to the surveyor only.

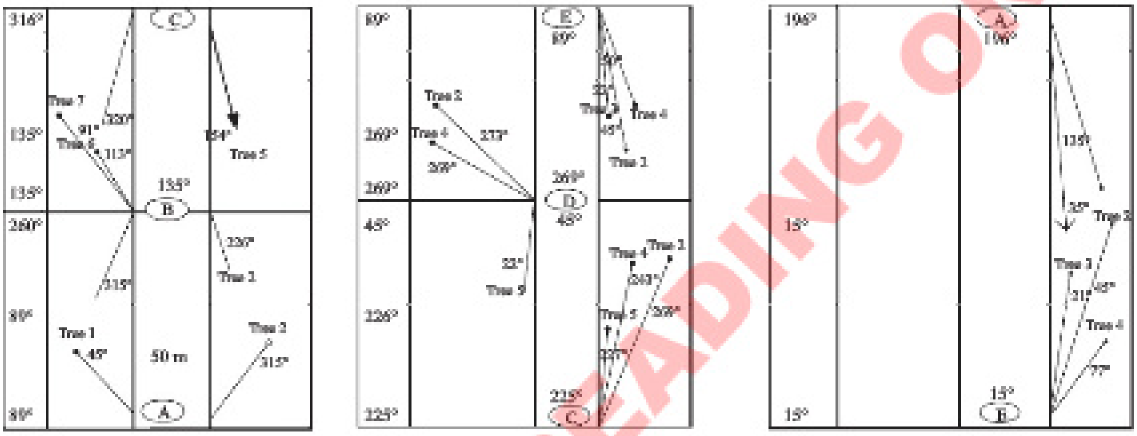


Figure 1.24: *Compass survey data recorded on field notebook*

From the field, surveyors collect and record data as shown in Figure 1.24. After the collection and recording of survey data, plotting follows. Plotting is therefore a transferring of the data from the field notebooks into graphical representation that can easily be understood and implemented. In plotting compass data, the following procedures are followed:

1. Prepare necessary materials for drawing, including drawing paper, a ruler, pencil, eraser and protractor.
2. Check whether the observed bearings are correct or not. If any attraction is detected, correct them.
3. Convert all magnetic bearings into true bearings.
4. Plot the true forward bearings and measured distance to a scale of your choice.
5. After the work, the surveyor produces a plan as shown in Figure 1.25.

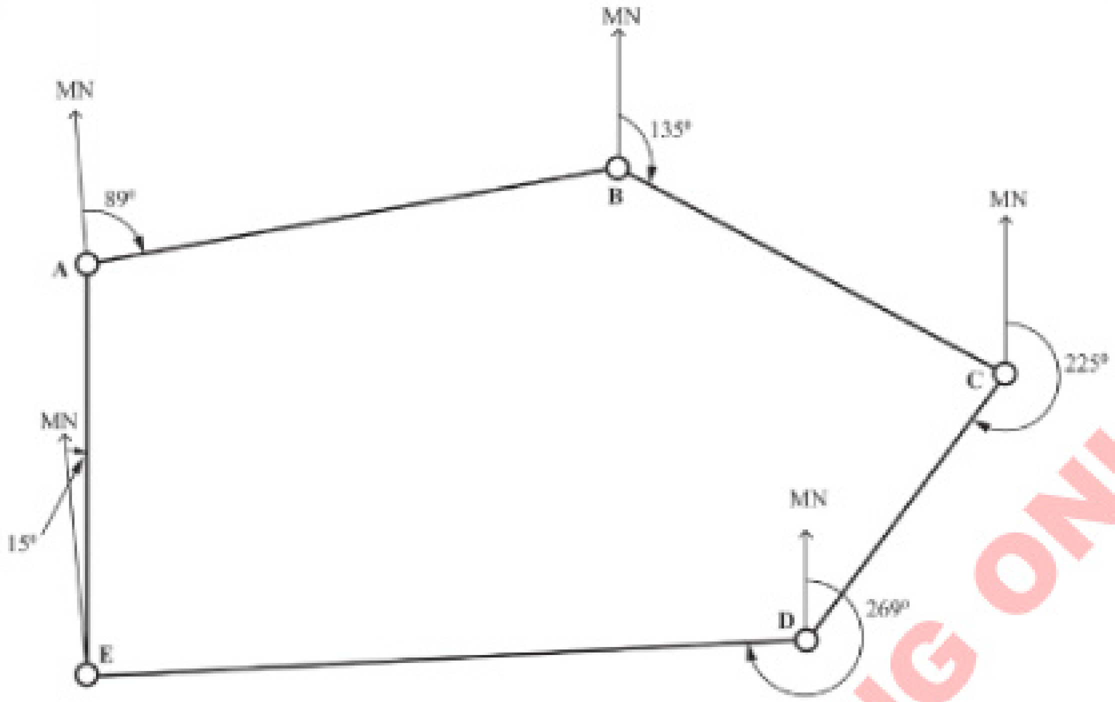


Figure 1.25: *Plot of field data*

Activity 1.3

1. Use the following back and forward bearings obtained for different framework lines ABCDE to answer the following questions;
   (a) Identify traverse stations with discrepancies.
   (b) Correct error if any discrepancy is observed.
   (c) Plot traverse ABCDE from the observed and corrected bearings.

Bearings of a traverse ABCDE

Line	Distance (m)	FB	BB
AB	40 m	60°	240°
BC	60 m	120°	300°
CD	100 m	210°	30°
DE	140 m	317°	135°

2. Mark corner points forming a boundary of a plot enclosing any building in your place, say a library, then do the following:

(a) Carry out a polygon traverse along the marked stations to measure forward bearing, back bearing and distances from one station to another.

(b) Plot the traverse using the measured bearings and distances.

(c) Using graphical method, convert errors in forward and back bearing.

Earth's magnetic field

Earth's magnetism is a result of the convection currents of molten iron and nickel in the earth's core. These currents carry streams of charged particles and generate magnetic fields. These magnetic fields deflect ionising charged particles from the sun (called solar wind) and prevent them from entering our atmosphere. Without preventing this magnetic shield, the solar wind could have slowly destroyed our life on Earth. Mars does not have a strong atmosphere that can sustain life because it does not have a magnetic field protecting it. The earth's magnetic field has three components that govern its magnitude and direction; namely; magnetic declination, magnetic inclination or the angle of dip and the horizontal component.

Magnetic declination

The horizontal angle between true north and magnetic north at the place and time of observation is what we term as *magnetic declination*. The angle of convergence between the true north and magnetic north at any place does not remain constant. It depends on the direction of the magnetic meridian at the time of observation. If the magnetic meridian is on the eastern side of true meridian, the angle of declination is called the *eastern declination* or *positive declination*. On the other hand, if the magnetic meridian is on the western side, the declination angle is called the *western declination* or *negative declination*. When both true North and magnetic meridians coincide, magnetic declination is zero.

The imaginary lines joining the places of equal declination either positive or negative, on the surface of the Earth, are called *Isogonic lines*. As the earth's magnetism is not regular and the intensity of its magnetic field also varies, the isogonic lines do not form complete circles but these follow irregular paths. The isogonic lines with zero declination are known as *Agonic lines*.

Determination of magnetic declination

True meridians and compass observations are important inputs in determining magnetic declination/variation of any place. True meridians in many places are determined by making astronomical observations, especially to stars. Compass observations are made by sighting of the true meridians at the places. The angle of inclination between the true meridian and the magnetic meridian given by a compass reading is the desired magnetic declination that can be determined as the difference between the true bearing and the magnetic bearing. Therefore; Magnetic declination = True bearing - Magnetic bearing. For instance, if the true and magnetic bearings of a line are 78° 45' and 75° 30', respectively, use negative sign for eastern declination and positive sign for western declination as shown in Figure 1.26. Therefore, the Magnetic Declination (MD) = 78°45' − 75°30' = 3°15'.

Having determined the magnetic bearing of a line and the magnetic declination at that place, the true bearing of the line may be calculated from the formula: True bearing = Magnetic bearing ± Magnetic declination. Similarly, to calculate magnetic bearing, we must be sure that we have calculated the true bearing of the line and the magnetic declination of that place. This formula can therefore be used:

Magnetic bearing = True bearing ± Magnetic declination

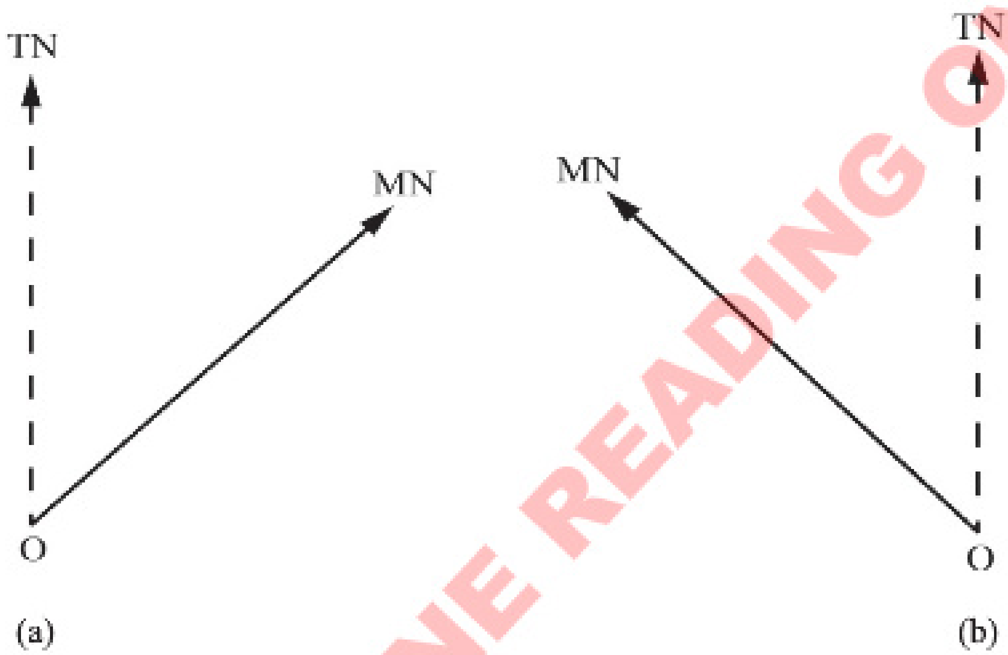


Figure 1.26: *(a) East declination and (b) West declination*

Variation of declination

The magnetic declination at any place does not remain constant but keeps on changing from time to time. It may thus increase or decrease. The changes can be classified as secular variation, annual variation, diurnal variation, and irregular variation.

(a) *Secular variation*

The continual changing of the magnetic meridian relative to geographical poles affects the declination of a place. Secular variation is a slow continuous change in declination of places. It alters the declination more frequently and in a less regular manner from year to year. Due to its greatness, secular variation is considered the most important for land surveyors. It appears to be of periodic character and follows a sine curve.

The swing of declination at a place over a period of centuries, may be compared to a simple harmonic motion. A secular change from year to year is also not uniform for any given place. It is also different for different places. To convert magnetic bearings into true bearings, an accurate amount of declination is essentially required. As such, it is important for a surveyor to know the exact amount of declination. When observations for the declination are made in different years of a century, it is revealed that magnetic meridian moves from one side of the true meridian to the other. The change produced annually by secular variation at different places amounts to from 0.02 minute to 12 minutes. The variation depends on the geographical position of different places. The annual secular change is the greatest near the middle point of meridians and the least at its extreme limits.

(b) *Annual variation*

This is the change in declination at a place over a period of one year. It is observed at different places over a period of 12 months. Annual variation is about 1 minute to 2 minutes, depending upon their geographical positions.

(c) *Diurnal variation*

The departure of declination from its mean value during a period of 24 hours at any place is called *diurnal variation.* The diurnal variation is a variation of the following variables:

(i) The geographical position of the place. Diurnal variation is the greatest for the places in higher latitudes and the least near the equator.

(ii) Season of the year. Diurnal variation is comparatively more in summer than in winter at the same place.

(iii) The time at the place. It is more during the day and less at night.

(iv) The year of the cycle. It is different in different years in the complete cycle of secular variation.

(d) *Irregular variation*

Abrupt changes of declinations at places due to magnetic storms, earthquakes and other solar influences, are called *irregular variations*. These disturbances may occur at any time and place and cannot be predicted. The displacement of a needle may vary in extent from 1° to 2°.

Magnetic dip

The magnetic dip is defined as the angle made with the horizontal line by the earth's magnetic field lines. It is also known as *dip angle* or *magnetic inclination* and was discovered by George Hartman in the year 1544. When the inclination is positive, it indicates that the earth's magnetic lines are pointing downward to the Northern Hemisphere and when the inclination is negative, it indicates that the earth's magnetic lines are pointing upward to the Southern Hemisphere.

In the year 1581, Robert Norman discovered a dip circle which is a method used to measure the dip angle. The other terms used are *isoclinic* lines (when the dip of the earth's magnetic field is the same along the line) and *aclinic* lines (when the locus of the points has zero dips).

Avoidance of errors in compass surveying

To reduce possible errors during a compass survey, the following are very crucial.

Check the accuracy of the compass by comparing it with an accurate compass or with location of magnetic north (MN) for the year of the survey with updated MN correction adjustment for field readings. Always check every reading with a back bearing and adjustment by adding or subtracting the mean of the error. Hold the compasses steady at 180° and ensure accuracy of all chain or tape measurements between ends of legs and to points of observation on legs.

Check that all conversions from magnetic bearing to true bearing are accurate and all scaled conversions are accurate. Ensure the booker takes down reading accurately by asking him to repeat where necessary. Avoid areas where there are deposits of metalliferous ores steel structures, metal gates, railway lines and others, which would influence reading. Avoid wearing metal rimmed spectacles, metal bangles or steel watches when using the compass.

Advantages of compass surveying

Compass surveying has the following advantages: First, fairly rapid method in the field, compared to other old survey methods, like simple chain survey. Secondly, a check can be made on all compass bearing, simply by calculating the forward and back bearings. Thirdly, cumulative error is reduced and can be easily rectified, with the help of advanced devices used. Fourthly, near and distant objects can be pin-pointed with accuracy by using various instruments which are able to accommodate the distance of the object. Fifthly, the method can be combined with other methods such as chain levelling and plane table, and in fact the prismatic compass is sometimes needed for mapping.

Disadvantages of compass surveying

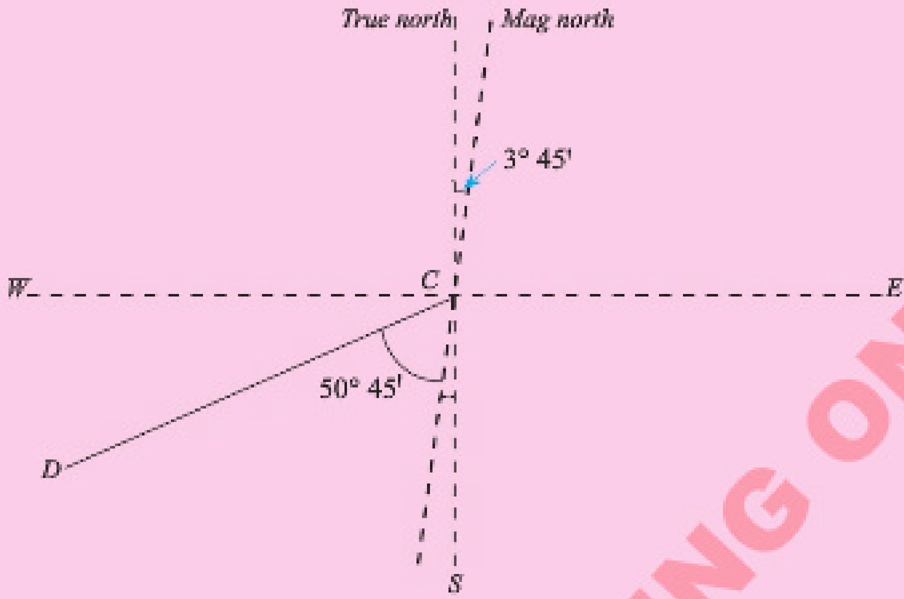
In elementary survey, compass observations over long distance objects cannot be checked by back bearings unless transport is provided. Human error is involved in taking as it is difficult to hold the compass absolutely steady; taking the mean of the difference between forward and back bearing reduces error but does not entirely eliminate it. The presence of ore bodies may not be known to the surveyor and this would affect readings. It is always better to consult the geological map or geologist first but the presence of iron ores in large quantity would necessitate using another method.

Activity 1.4

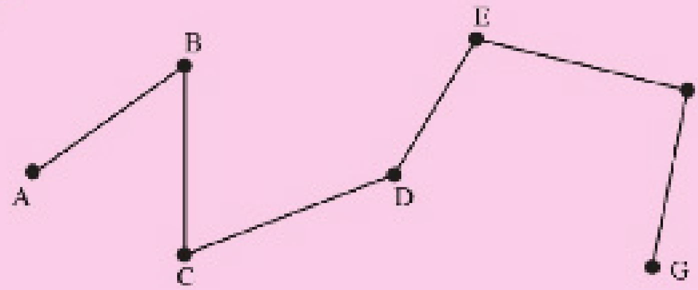
Suppose your school is planning to demarcate a plot for planting flowers within the school compound. Use the knowledge and skills acquired in compass surveying to map the desired plot.

Exercise 1.1

1. Calculate the true bearing of line CD if its magnetic bearing is S 50° 45' W and the declination is 3° 45' E.



2. In an old map, a survey line was drawn with a magnetic bearing of 202°W when the declination was 2° W. Find the magnetic bearing of the line at a time when magnetic declination was 2° E.
3. In 1935, a certain line had a magnetic bearing of S 67° 30′ E and then the magnetic declination at that place was 8° E. In 1977, the magnetic declination was 4° W. Find the magnetic bearing of the line in 1977.
4. Discuss how diurnal variation affects magnetic declination of the Earth.
5. Explain why correcting closing error in compass traverse is important.
6. Convert the following bearing observed in whole circle bearing (WCB) system to quadrant bearing system (QBS): (a) 65° 40' (b) 135° (c) 265° 25' (d) 305° 45'.
7. An open compass traverse was run from station A through B, C, D, E, F, and G as shown in Traverse ABCDEFG.



The observed forward and backward bearings in traverse ABCDEFG are shown in the following table.

Observed bearings in traverse ABCDEFG

Line	FB	BB
AB	45° 00'	225° 30'
BC	178° 50'	359° 00'
CD	82° 00'	263° 00'
DE	45° 00'	225° 00'
EF	100° 30'	280° 50'
FG	205° 45'	25° 55'

Use the observed bearings to:

(a) Identify a traverse line which is free from local attraction.

(b) Correct bearings of all traverse lines starting from the line which is free from local attraction.

8. By using the observed magnetic bearings and distances in a closed traverse ABCDE', do the following:

(a) Plot a traverse and measure the closing error.

(b) Correct the traverse by graphical method.

Magnetic bearing and distance in a closed traverse ABCDEA

Line	FB	BB	Distance (m)
AB	45° 00'	225° 20'	40
BC	100° 00'	280° 30'	50
CD	160° 30'	340° 30'	40
DE	250° 00'	70° 10'	51
EA	312° 00'	132° 00'	57

9. The position of a square dining hall relative to a certain visible baseline is to be determined. Giving reasons, select the appropriate compass surveying method for the task.

Plane table survey

Plane table surveying is a graphical method of survey in which the field observation and plotting are done simultaneously. It is a graphical construction of straight lines, angles, and triangles for plotting the ground detail points. This method of land surveying is simple and cheaper than theodolite survey but only suitable on small areas. The plan is drawn by the surveyor in the field while the area to be surveyed is in front of his eyes. Therefore, there is low possibility of omitting the necessary measurements. Hence, the method has very low chances for committing errors.

Just as it is for the case of compass and chain surveying, plane table surveying is named after the principal instrument used, the plane table. The earliest mention of plane table and plane table surveying dates back to 1551 when Abel Faullon described the method. Prior to 1830, the method was called *plane table* (Figure 1.27).

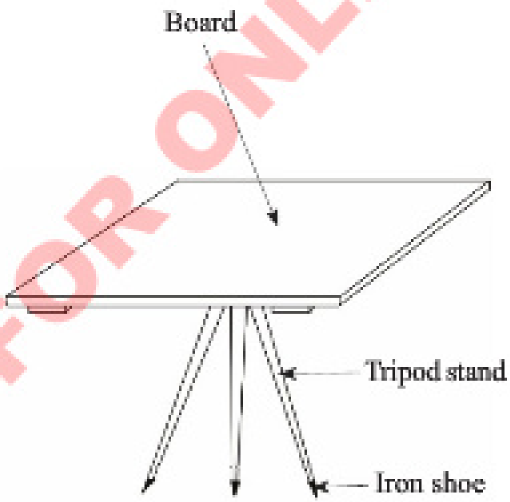


Figure 1.27: *Plane table*

Principles of plane table survey

The plane table technique operates on the principle that every established ray to various details must pass through the survey station. This principle is called *parallelism,* which means that all the lines drawn through various details should pass through the survey station. This principle can be best understood by considering the graphical reduction of a triangle to the given dimensions. The base of the triangle is plotted on the desired scale and the base angles are plotted directly by turning the alidade at each end. In plain table survey, the position of plane table at each station must be maintained identical, that is, at each survey station the table must be oriented by magnetic north.

Equipment used in plane table survey

In plane table survey equipment can be grouped into basic equipment and accessories. Basic equipment includes a plane table, tripod stand and alidade. While accessories include trough compass, plumbing fork, plumb bob, chain or tape and ranging poles spirit level, U-fork, water proof cover, drawing paper, pins, pencil and eraser.

Plane table: this is the principal equipment in plane table surveying. It is a board from which rays to the target objects are established, measured and located. Drawing board for plane tabling is made up of well-seasoned wood with its upper surface exactly plane.

Plane tables are in a number of sizes. The common dimensions of plane tables are those rectangular in shape with size 75 cm × 60 cm. Plane table comes with wooden or aluminium tripod stand to mount on during the surveying process as shown in Figure 1.28(b). They are provided with clamps to fix it in any direction. The table can revolve around its vertical axis and can be clamped in any position when necessary.

Tripod stand as shown in Figure 1.28(a) is provided with three-adjustable legs for adjusting the height of the plane table. The height of the tripod stand is normally 120 cm.

Figure 1.28(a): *Tripod stand*

Figure 1.28(b): *Tripod stand with plane table*

Alidade is a multi-task equipment useful throughout plane table surveying in assisting as a ruler and a sighting instrument. It is a straight edged ruler, attached with a sighting device. One edge of the ruler is bevelled and graduated. Usually, the graduated edge is used for drawing lines of sight to objects from the plane table station. There are two types of alidades available for plane tabling: the *simple alidade* and *telescopic alidade*.

Simple alidade is used for ordinary work. It consists of gun-metal or wooden ruler with two vertical vanes at the ends. The eye-vane is provided with a narrow slit while the object vane is open and carries a horse hair. Both slits provide a definite line of sight which can be made to pass through the object to be sighted. To draw the rays, one of the edges of the alidade in Figure 1.29 is bevelled and its perfectly smooth working edge is known as the fiducial edge. The fiducial edge is graduated to facilitate the plotting of distances to a scale.

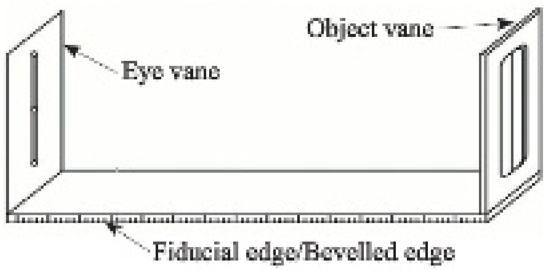


Figure 1.29: *Simple alidade*

Telescopic alidade in Figure 1.30 is used when it is required to take inclined sights. It essentially consists of a small telescope with a level tube and graduated arc mounted on horizontal axis. It gives higher accuracy and more range of sight.

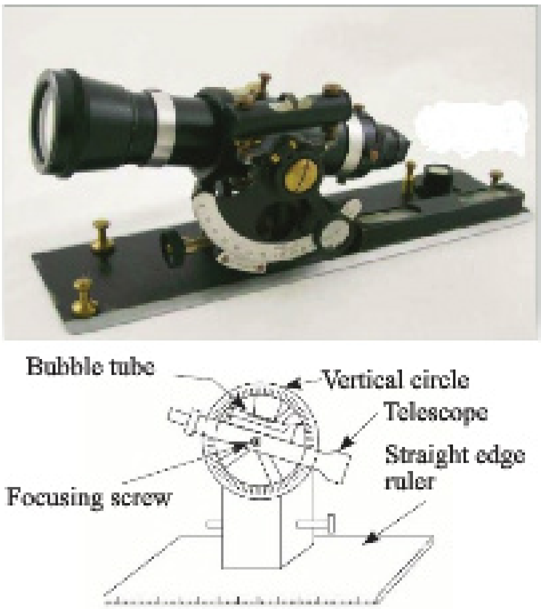


Figure 1.30: *Telescopic alidade*

Trough compass in Figure 1.31 is a thin, narrow, wooden box containing a magnetic needle of about 120 mm long. The box is moved around on plane table surface so that when the needle points to the magnetic North, it is parallel to the sides of the box. The trough compass is required for drawing the line showing magnetic meridian on the paper. It is also used to orient the table to the magnetic meridian.

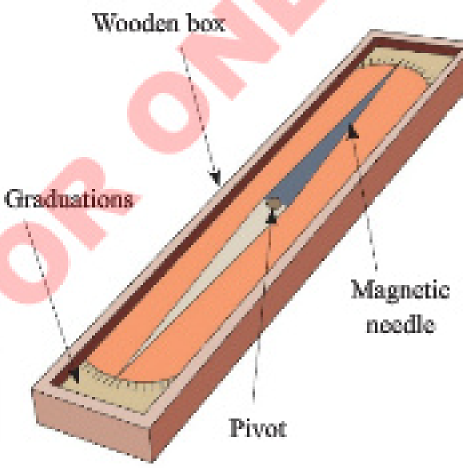


Figure 1.31: *Trough compass*

Spirit levels are common and cheaply available for masonries. They are flat-based aluminium or woody bar fitted with bubble tube and are used for levelling in brick laying. In plane table surveying, spirit levels are used to level the plane table during surveying or ascertaining if the table is properly levelled. The levelling of the board is done by placing the level on the board in two positions at right angles and getting the bubble to the centre of bubble tube. To ensure that the plane table is perfectly levelled, a bubble of spirit level must be at the centre of the bubble tube and checked with its positions in any two mutually perpendicular directions as indicated in Figure 1.32.

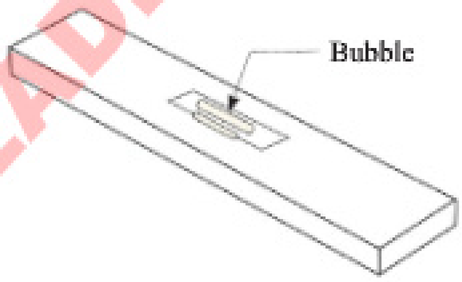


Figure 1.32: *Spirit level*

Apart from the instruments for the plane table, there are also accessories which include the following:

U-fork with plumb bob is used for cantering the table over the survey station. U-fork is also called a *U-frame*. It is attached on the plane table during the field plotting and fixed with a plumb bob to point on a station when the plotted position of that point is already on the sheet. In the beginning of the work, the U-fork with its plumb bob is used to transfer the ground point onto the sheet as indicated in Figure 1.33.

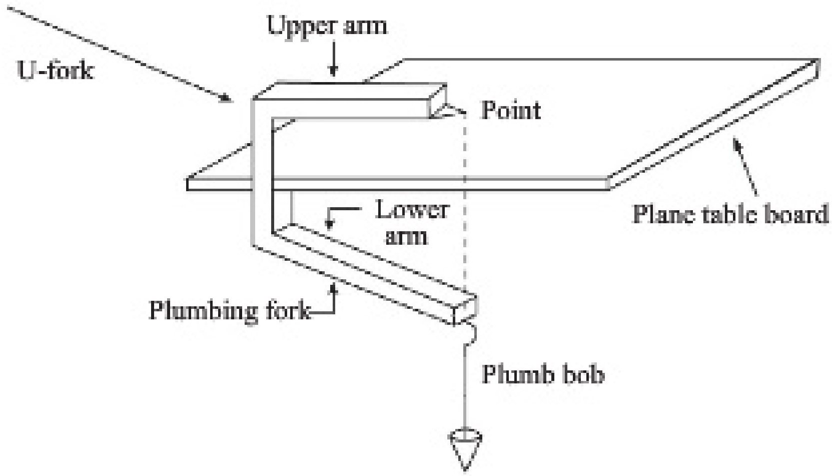


Figure 1.33: *U-fork with plumb bob*

Note that u-forks appear in different shapes as indicated in Figure 1.34 (a, b, and c).

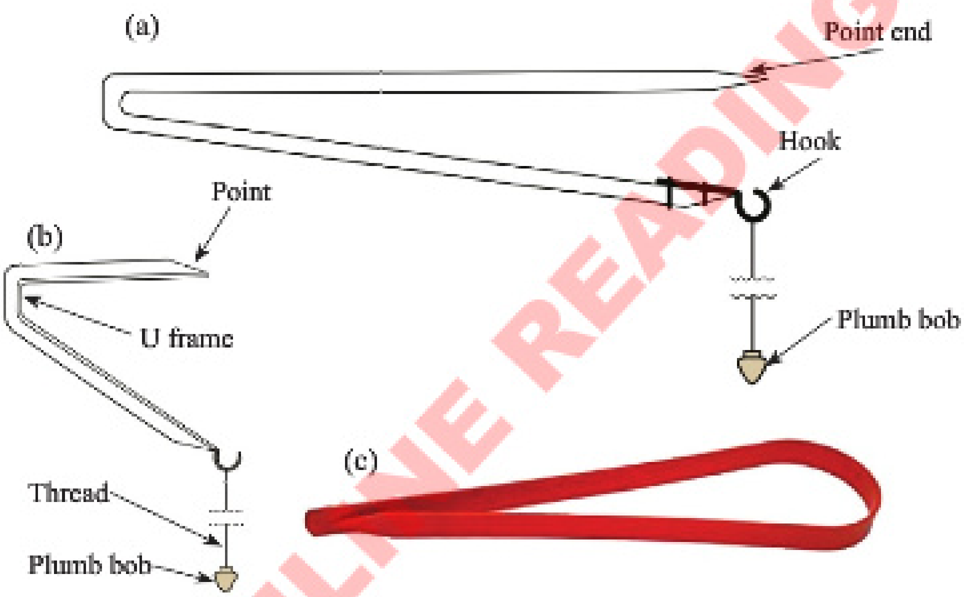


Figure 1.34: *Different shapes of u-forks*

Field practical operations

It should be noted that, proper handling of the plane table equipment and its accessories, performing surveying activities diligently in accordance with the practice and rules which ultimately build a foundation for obtaining reliable, and accurate field data is very important. In performing plane table surveying, two main steps are involved: *Setting up a plane table* and *locating the position of points or features* as required.

1. Setting up the plane table over the chosen station

Setting up a plane table involves three operations: cantering, levelling and orienting. Cantering the plane table means putting the table exactly over the starting point you have chosen. The procedure involves setting up of the tripod by fixing them firmly and properly spreading them on the ground, and mounting a plane table board on a tripod at a convenient height. The table should be approximately levelled by tripod legs by judging by the eyes. Then, the operation of cantering is carried out by means of a u-frame and plumb bob.

Cantering is a preliminary stage to plane tabling. After mounting the board, a point on the ground is transferred to a paper sheet, laid on top of the board as shown in Figure 1.35.

Figure 1.35: *Plane table on ground beacon station*

The table is then levelled using the spirit level (Figure 1.36). After mounting a plane table on the tripod stand, the process of making the plane table perfectly horizontal is what we phrase in this book as *plane table levelling*. The spirit level is placed parallel to the two perpendicular sides of a plane table at each corner. Then, its bubble is brought to the centre by either turning the three foot-screws or adjusting the three legs of a tripod stand.

Figure 1.36: *Spirit level*

Orienting the table is another equally important and necessary process for setting up the plane table before any measurement is taken. It is the process of aligning the plane table in such a way that, all the lines plotted on a sheet are parallel to corresponding lines on the ground. The procedures and processes of making lines drawn on a sheet of paper parallel to the corresponding lines on the ground are referred to as *orientation of plane table*. The accuracy of plane table survey mainly depends upon the accuracy of plane table orientation at each station point. The orientation of a plane table can be achieved by either trough compass or back-sighting method. Therefore, orientation here means assuring that the plane table is strictly oriented towards the magnetic meridian.

In orienting by using a trough compass, a line representing a meridian is drawn on a sheet of paper to orient the plane table. A trough compass is then placed along this line, and the table is turned until the trough compass points towards the north-south direction. At this position, the plane table is clamped. This method is quick but unsuitable in areas with metal ferric ores which affect the direction of magnetic needle due to local attractions.

Procedures for orienting plane table by trough compass method is shown in Figure 1.37 below.

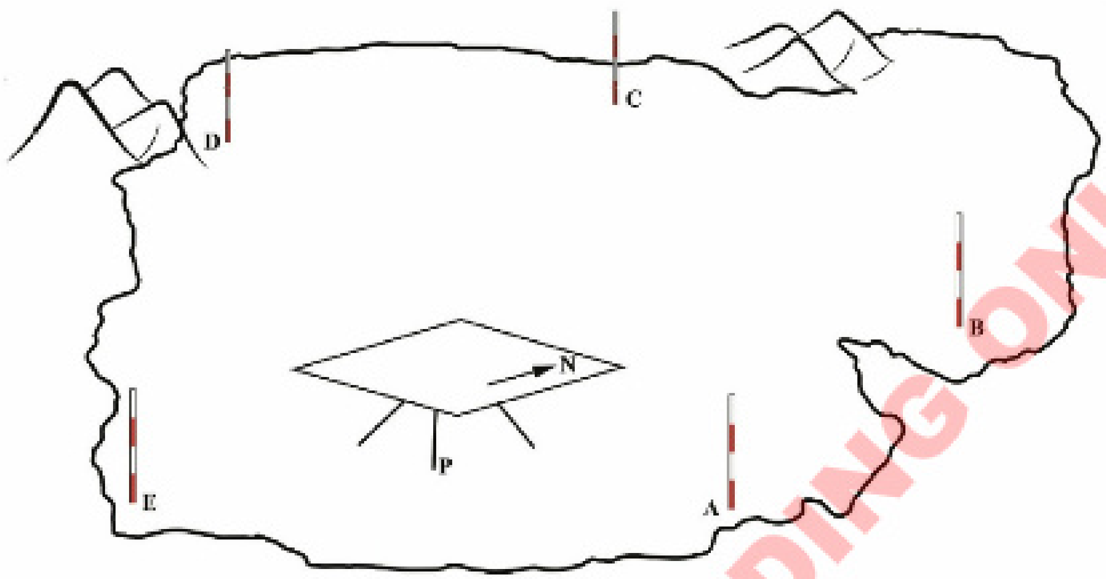


Figure 1.37: *Plane tabling the farm ABCDE*

The procedures are further explained below:

(i) Set the plane table at P and perform centering and levelling using spirit level as described in the preceding paragraphs. Put a mark on a paper sheet at a point above point P. The point P is transferred to *p* on the sheet of paper by using U-fork and plumb bob;

(ii) Using a trough compass, establish the north direction somewhere on the right-hand side on the sheet of paper. To indicate north direction, place a trough compass where you would like to draw it and keep twisting to make sure a compass arrow points to the North. After that, draw a line towards the meridian as shown by a compass to indicate north direction as shown in Figure 1.37. After fixing the north direction, then the direction to orient a plane table is ready and all lines will be drawn parallel to it; and

(iii) Start taking measurements from the table to the established stations.

The orientation by back-sighting is a common method used in plane table surveying. After finishing surveying from the plane table at A, if the table is to be shifted to station B, a line is drawn from the plotted position of station A towards station B. Then distance AB is measured, scaled-down, and the plotted position of station B is obtained. The table is then shifted to station B, centered and levelled. Keeping alidade along line BA, the table is turned to sight station A and clamped. Thus, the orientation of the table is achieved by the back sighting. Orientation may be checked by observing already plotted objects.

Therefore, the orientation procedures in plane table survey aim at making sure that the plane table at each station is parallel to the position which was occupied at the first station. Hence, the emergence of the principle of *parallelism*.

2. Locating position of points or features

Different types of surveys accomplish one important objective: locating or positioning of both natural and man-made features. Plane table survey also accomplishes this objective. Plane table survey may be done for the purpose of updating information in a school map by locating the new infrastructure established recently or demarcating land parcels for housing, farming and others.

In plane table surveying, the position of points or features is determined by scaling down the measured distances and plotting them on a drawing sheet. There are four common methods used to determine the position of points or features in a plane table, which are *radiation, intersection or triangulation, traverse and resection*.

Plane table survey by radiation method

Radiation is a method in which all measurements start from one point on the plane table out widely to the objects or details of interest. Radiation method is only effective when the entire area can be surveyed from one single station. In this method, the plane table is set up at one station from where all the other points that need to be fixed are visible. For example, positions of points A, B, C, D, and E in a farm, which are visible from station P in Figure 1.38, can be fixed using the radiation method by following the following procedures:

1. Set up a plane table at point P where all other points to be fixed (that is, A, B, C, D, and E) are easily seen. Then, decide a scale for the measurement that you are going to make, let's say, *1cm represents 10 metres*. However, the preliminary set up of the plane table must be conducted as directed in the plane table setting section on page 31 of this book.

2. Put the alidade on point 'p' marked on the drawing paper vertically above point 'P', and the first point, say A is sighted from it. A ground distance from P to A is measured and presented on the sheet of paper as 's' along the line of sight connecting points P and A as shown in Figure 1.38.

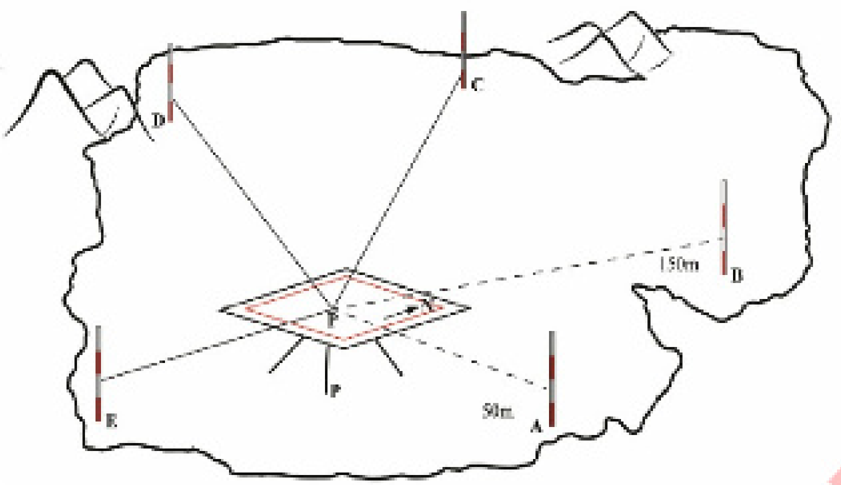


Figure 1.38: *Plane tabling setup and procedures*

Continue sighting other stations B, C, D and E; measure their respective distance from point P and present them on the papers as '*b*', '*c*', '*d*', and '*e*' as shown in Figure 1.39.

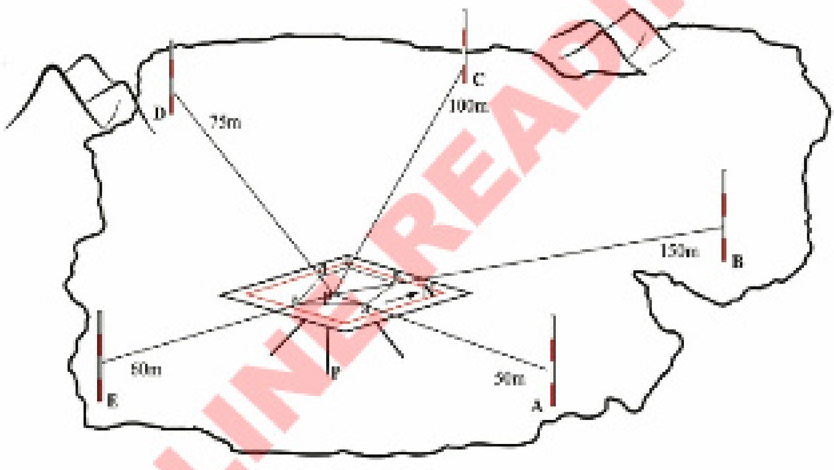


Figure 1.39: *Farm ABCDE*

3. Then, join the points 'a', 'b', 'c', 'd', and 'e' as shown in Figure 1.39; and
4. Finally, produce a plan of the farm surveyed. However, it should be remembered that, point 'P' must be located in such a way that if a surveyor is not there and the plan is found, any other person can determine its location.

Generally, the points that the surveyor wants to locate are boundary points A, B, C, D and E. In this case, point 'P' is just a reference point from which the stations A, B, C, D and E can be identified. It should be remembered that A, B, C, D, and E can also be used to locate 'P'. It must also be remember that radiation method fixes location or position of details from a single point.

Plane table survey by intersection method

Different from radiation method, where a line of sight is defined and the distance to a fixed point is measured, in intersection method, only a line of sight is defined. This means that in order for a point or feature such as a building and a water well to be fixed, two lines of sight are defined from two different points towards a point to be fixed. For example, two corners, A and B, of one side of a building, are fixed using the intersection method from two points, S1 and S2.

For instance, in the Figure 1.40 below, if the interest is to locate a school building from point S2 near the water tank and point S1 near the headmaster's house, a plane table survey through intersection method will go through the following procedures:

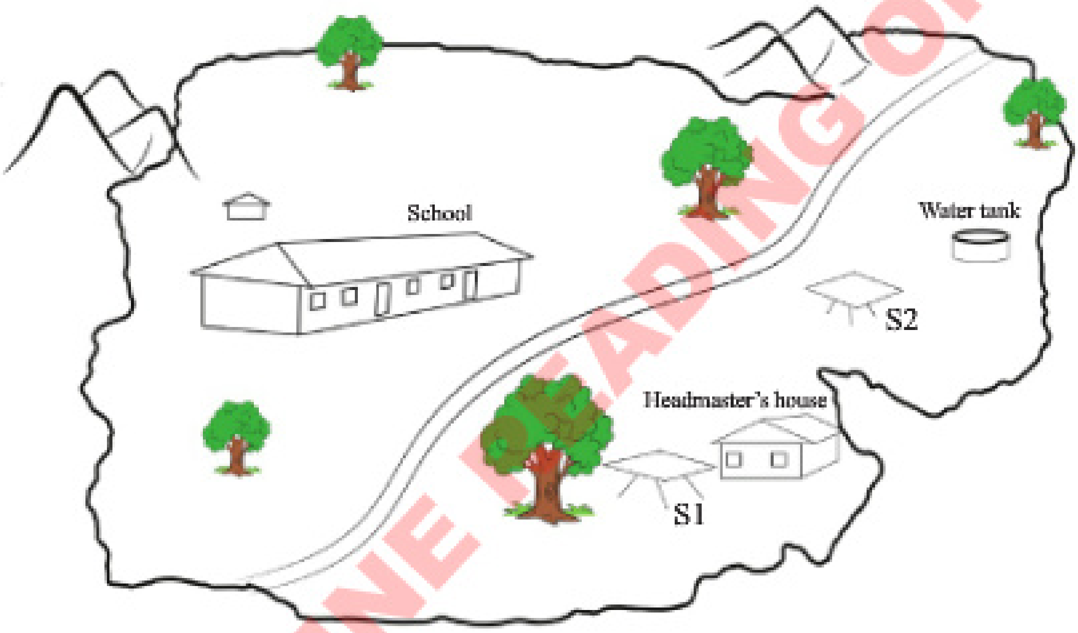


Figure 1.40: *Plane table setting at stations S1 and S2*

1. Firstly, setting up a plane table at stations where points A and B can easily be seen. In Figure 1.40, we establish stations S1 and S2.
2. Secondly, the alidade is put on point 's1' marked on the drawing paper vertically above point S1 and A is sighted from S1. The line of sight connecting points S1 and A is drawn. The same is done to S1 and B which are also drawn on a drawing paper.
3. Thirdly, a baseline connecting stations 's1' and 's2' on the sheet of paper is defined by measuring the distance between stations S1 and S2 on the ground and plotting it to a suitable scale on the sheet of paper between points S1 and S2 (Figure 1.41).

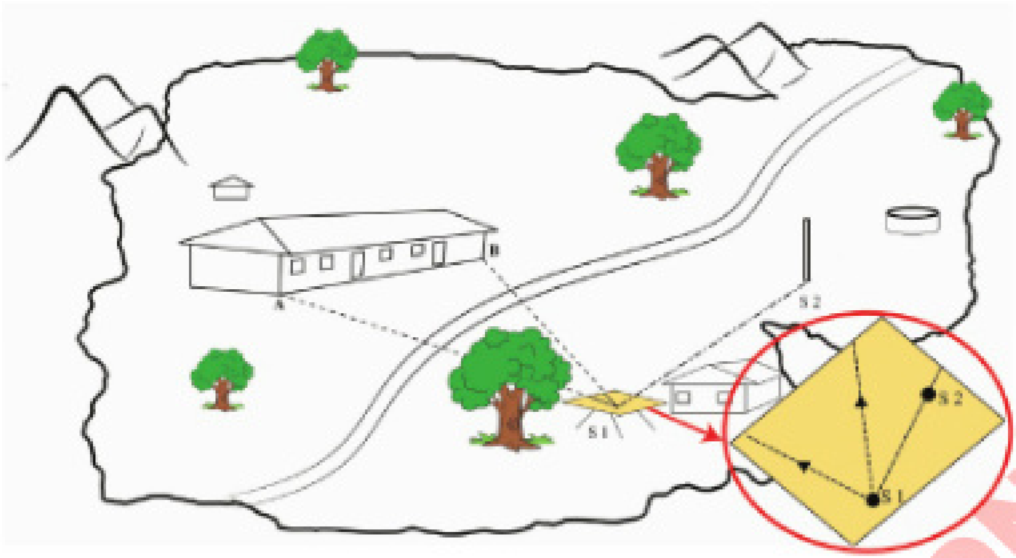


Figure 1.41 (a): *Sighting station A and B from S1*

4. In the fourth step, the plane table is moved to station S2 and set up such that s2 is vertically above point S2. Then, the alidade is put along a line connecting points S2 and S1. The plane table is turned horizontally about a vertical axis until the alidade bisects a ranging pole held at station S1 and the table is clamped.

5. Finally, the alidade is put on point S2, turned to bisect stations A and B to define their respective lines of sight on the drawing paper as 'a'. The point where lines of sight for station A from stations S1 and S2 intersect is a position of point A, marked on the drawing paper. Similarly, the point where lines of sight for station B from stations S1 and S2 intersect is the position of point B, marked as b on the drawing paper.

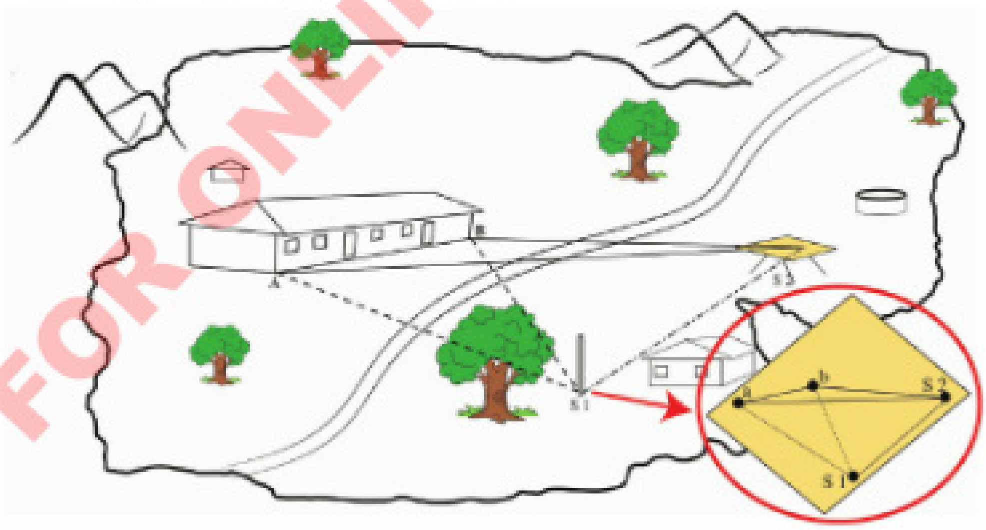


Figure 1.41 (b): *Sighting station A and B from S2*

Plane table survey by traverse method

This method has been used in chain and prismatic surveying. Traverse involves establishing a series of connected lines whose positions are to be determined. The traverse method in plane table surveying is different from the traverse method in chain and prismatic surveying. In plane table survey, plotting is done instantly in the field. Plane table is also used in fixing survey lines between stations of a closed or open traverse. Through traverse method, a plane table is set up at each traverse station. For example, traverse method is used to fix five corners A, B, C, D and E of a farm in Figure 1.42.

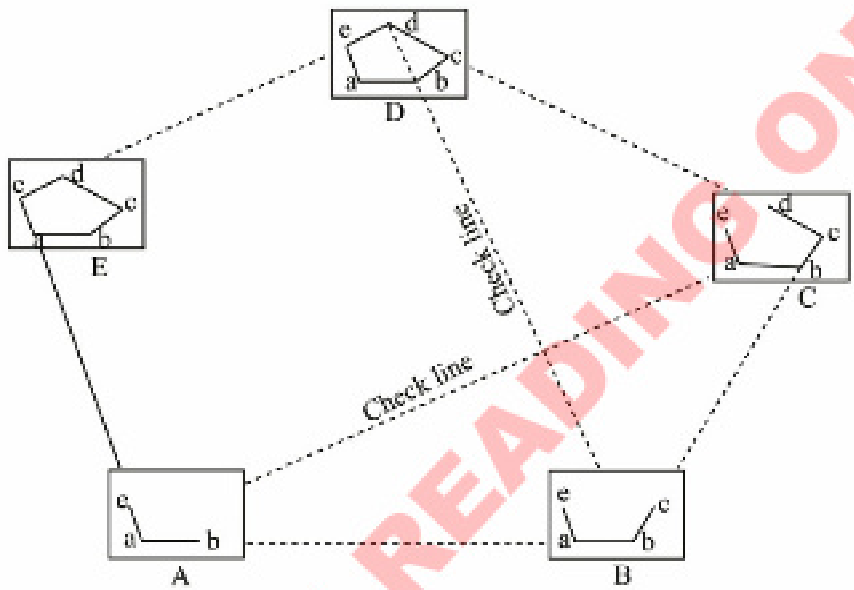


Figure 1.42: *Fixing positions of five corners A, B, C, D, and E of a farm using traverse methods of plane table surveying*

The following procedures are followed to fix positions of points using traverse method in plane table survey:

1. A plane table is set up at one of the corner points, say corner point 'A', where the next corner point, say 'B', is easily seen. The setting-up involves the procedures discussed earlier.
2. From point 'A', a sight is taken towards B and the distance AB is measured and plotted to a suitable scale as '**ab**' on the drawing sheet.
3. The plane table is moved to station 'B' and set up such that 'b' is vertically above 'B'. Then, the alidade is put along the line connecting points 'b' and 'a'. The plane table is turned horizontally about a vertical axis until the alidade bisects a ranging pole held at station 'A', the table is then clamped.
4. The alidade is put on point 'b', turned to sight a ranging rod held at C, then the line of sight connecting points B and C is

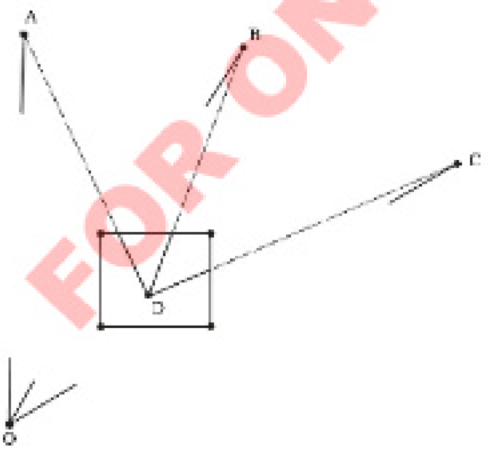
drawn on a drawing sheet. The distance BC is measured and plotted to a suitable scale.

5. Steps (3) and (4) are repeated for traverse stations C, D, and E.

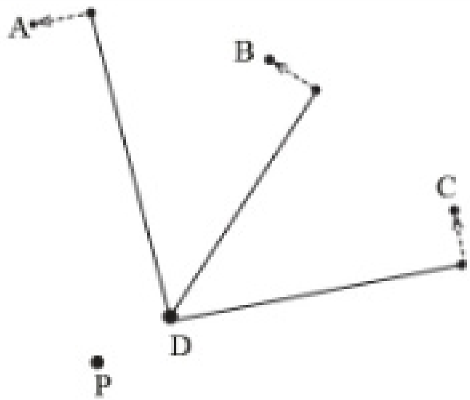
Plane table survey by resection method

Resection is the method used in determining a location of an unknown point in relation to known points. The plane table is fixed at an unknown point to allow sighting of points of known positions. The method is usually applied when some objects may be difficult to be seen from the baseline stations.

To do this, the board is moved to the position of the object position, oriented by trough compass and clamped. Rays are drawn on a tracing paper from three objects in the fields A, B, and C as shown in Figure 1.43. If the board is correctly oriented, the rays will intersect at unknown point D. If the positions of rays A, B, and C coincide with their positions on the map, the position of D can then be established on the map.



(a)



(b)

Figure 1.43: *Fixing the position of objects by plane table resection method*

However, due to incorrect orientation, the rays may form a small triangle with D either within or outside the triangle. This is referred to as the triangle of error. The error can be fixed through the following procedures:

Case 1

(i) If the position of D is within the triangle of error, it can be found by drawing short lines within the triangle, each line drawn vertically from the ray line and proportional to the length of their respective rays. If they are properly drawn with a compass, they should intersect at D position as shown in Figure 1.44.

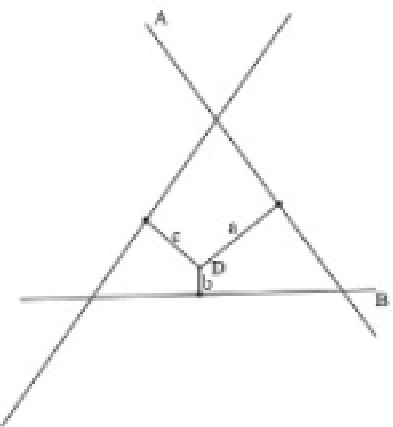


Figure 1.44: *Correcting error when point D is within the triangle*

(ii) To check the new position of D, lay the alidade on D, turn the board slightly until A and D are aligned and draw a new ray. Do the same for B and C. The new rays should meet at point D. If they do not, repeat the process.

Case 2

(i) If the position of D lies outside the triangle of error, point A, B, and C being in front of the observer, D may be on the right or left of the triangle of error. The board may be moved slightly to the right to orient it correctly with A, B, and C. Thus, the position of D will be to the left. To fix D, use vertical lines from rays proportional to the length of the rays as shown in Figure 1.45.

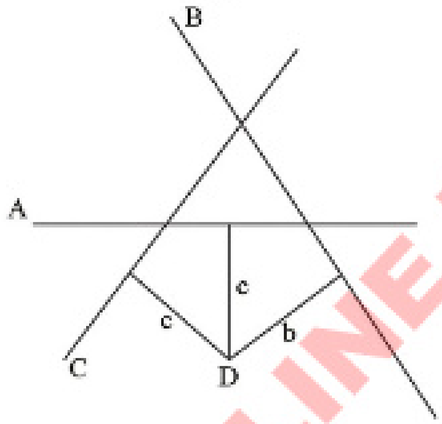


Figure 1.45: *Correcting error when point D is outside the triangle*

Source of errors in plane table survey

Plane tabling, like other survey methods, is not free from errors. Errors in plane table survey could fall into three categories, mainly instrumental errors, errors in manipulation and sighting, and errors in plotting. Instrumental errors include instability of the table due to the shrinking of the paper, thickness of the pencil and faults related with poor or failure of proper setting of the plane table at the start. Some faults from human error include improper setting of the drawing board, improper setting of the fixing clamp and alidade not being parallel with the line of sight. Errors from manipulation include those resulting from defective levelling, sighting, orientation, and cantering. Consistently, defective scale of a map and wrongly intersecting the rays drawn from two different stations contribute highly to production of faulty survey data.

Significantly, plane table surveying is a simple and rapid method for survey works on small land areas whereby a map or plan can be produced. The method avoids omission of features as both measurements and plotting are done in the field. More so, the method demands fairly simple skills. It is also more field-based, with minimised possibility of making mistakes.

Despite the advantages mentioned, plane table surveying has some limitation: the method cannot be used in rainy and windy conditions. Apart from that, the plane table equipment is heavy to carry, so this may require the use of a car which adds expenses. A single error in the ground base line measurement can throw out all angle measurements. Again, the table uses a lot of equipment and accessories which are easier to forget while in the field. Lastly, the method cannot be used for a large scale survey.

Activity 1.5

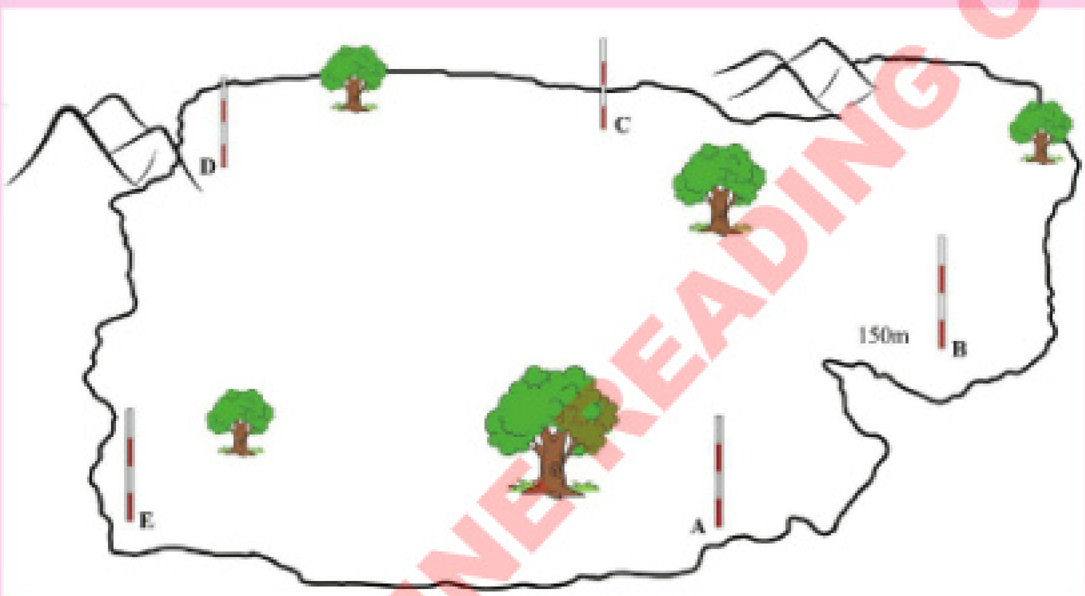
Suppose your school intends to map an area for opening up a school garden project within the existing school plan, use the acquired knowledge and skills on plane table survey to plot the area.

Exercise 1.2

1. Describe resection in plane table survey.
2. (a) Explain the advantages of plane table survey.

    (b) Write short notes on the importance of cantering in the plane table survey.

    (c) Describe two problems in plane table survey.
3. What do you understand by the term 'orientation' as used in plane table survey?
4. Show the effect of bad orientation on traverse.
5. Describe how you would carry out plane table survey by traverse method of the area provided in the following figure.



6. The connect points defining the boundary of a farm are visible from point P, but not from the preceding and next point. Explain how you would survey the corner points using plane table survey.
7. Compare and contrast the following surveying methods:

    (a) Compass traversing and plane table traversing

    (b) Radiation and intersection methods
8. (a) What is meant by triangle of error and how can one deal with it in setting a plane table?

    (b) Illustrate the intersection in plane table surveys.
9. Describe five (5) equipment used in plane table survey.

Levelling survey

Levelling is a method of land survey that focuses on determining the heights of given points above or below a *datum* line or determining difference in elevation between points. Datum is the surface with respect to which levels of other points are determined.

Levelling survey derives its name from the survey objective, levelling, and its principal equipment level. Mentioning the word "level" may seem new, but it has been used quite often in our daily activities. A spirit level shown in Figure 1.46 is the most common level that is used in masonry works, especially, maintaining perfect wall horizontality and verticality during brick laying.

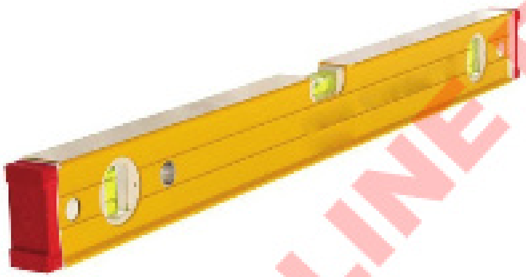


Figure 1.46: *Spirit level*

Levelling survey uses the same principles used by masons to maintain the horizontality and verticality during brick laying. Levelling survey has been very useful in contouring, preparing land cross section and longitudinal section. Levelling survey provides data helpful for construction works of narrow sections of the Earth such as sewers, pipelines, roads and railways.

Common terms in levelling survey

There are many special and non-special terms commonly used in levelling. Some of these are highlighted in this section.

Instrument station: is the point where instrument is set up for observations.

Station: is the point where levelling staff is held. It is the point whose elevation is to be determined or the point that is to be established at a given elevation.

Height of instrument (HI): is the elevation of the line of sight with respect to the assumed datum. It is also referred to as *height of collimation (HC)*. In levelling, however, HI does not mean the height of the telescope above the ground level where the level is set up.

Back sight (BS): is the first sight taken on a levelling staff held at point of known elevation. It ascertains the amount by which the line of sight is above or below the elevation of the point. BS enables the surveyor to obtain the height of the instrument.

Fore sight (FS): is the sight taken on a levelling staff held at a point of unknown elevation to ascertain the amount by which the point is above or below the line of sight. FS enables the surveyor to obtain the elevation of the point. It is also generally known as *minus sight* as the foresight reading is always subtracted from the height of the instrument (except when the staff is held inverted) to obtain the elevation.

Change point (CP): is a point on which both the fore sight and back sight are taken during the operation of levelling. Two sights are taken from two different instrument stations, a fore sight to ascertain the elevation of the point while a back sight is taken on the same point to establish the height of the instrument of the new setting of the level.

Intermediate sight (IS): is the fore sight taken on a levelling staff held at a point between two change points or a benchmark and a change point, to determine the elevation of that point. It may be noted that IS are stations sighted between BS and FS.

Bench mark (BM): refers to a relatively permanent and fixed reference point of known elevation above the assumed datum.

Line of collimation (LC): refers to the line passing through the optical centre of the objective and the point of intersection of the crosshairs stretched in front of the eye piece and its continuation.

Line of sight (LS): refers to a line passing through the optical centre of the objective, traversing the eye-piece and entering the eye.

Vertical datum: refers to any level surface to which elevations are referenced. Mean sea level is one of the vertical datum assigned on elevation or reduced level of zero.

Mean sea level datum (M.S.L): is a mean sea level obtained by making hourly observations of the tides at any place over a period of 19 years. The *M.S.L* datum adopted by the survey of India for determining the elevations of different points in India is that of Mumbai. In East Africa, the datum line is situated in Mombasa, while in Nigeria it is in Lagos and for South Africa, it is in Cape Town.

Reduced Level (R.L): is the height or depth of a point above or below the assumed datum. It is also known as elevation of the point. Elevations of the points below the datum surface are known as *negative elevations*.

Vertical line: is a line that follows the local direction of gravity as indicated by a plumb line.

Level surface: is a curved surface that at every point is perpendicular to the local plumb line (i.e., the direction in which gravity acts).

Level line: is a curved line on a level surface.

Horizontal plane: is a plane perpendicular to the local direction of gravity and tangential to the level surface.

Horizontal line: is a line on a horizontal plane which is perpendicular to the vertical line.

Vertical control: is a series of benchmarks or other points of known elevation established throughout an area.

Equipment used in levelling survey

Traditional levelling survey requires three major equipment for its operations. The equipment includes a level, tripod stand and a levelling staff. A level is an instrument with a telescope, a bubble tube and a levelling head used for sighting targets, particularly levelling staff (Figure 1.47). A telescope is an optical instrument mounted on levels to magnify and view distant objects. It provides a line of sight. A bubble tube is used together with the levelling head to make the line of sight horizontal by bringing the bubble to the centre of its run.

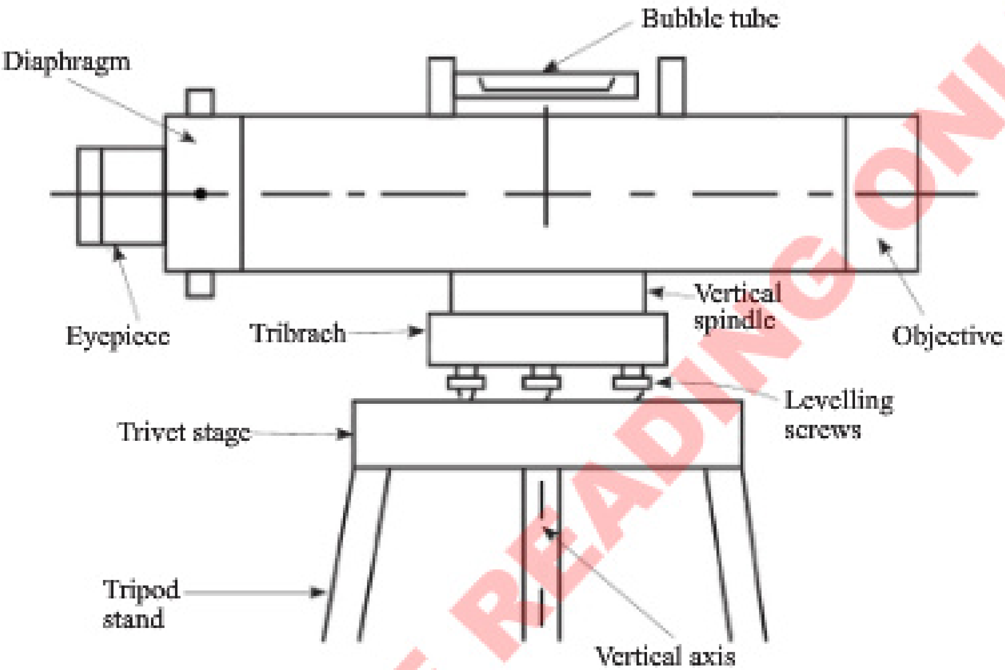


Figure 1.47: *Components of a level instrument*

There are three basic types of level instruments, namely: *Dumpy levels, engineers'* or *tilting levels* and *automatic levels*. Of the three, the first two are spirit bubble levels. The dumpy level is a simple basic instrument, while the tilting level has been modified to give it greater convenience of operation and a possibility of greater clarity. However, the most often used and "quick set" level is a tilting level without foot-screws. The automatic types of levels which give a horizontal line of sight automatically, are the most favorable to use, but they are relatively expensive.

The three basic types of level instruments are explained below

(a) *Dumpy level:* is characterized by their telescope being rigidly attached to the vertical spindle as shown in Figure 1.48. The levelling of the instrument is done by means of three-foot screws separating their two plates. The upper plate with the vertical spindle on which the telescope and bubble tube are mounted has to be levelled with the foot screws.

Figure 1.48: *Dumpy level*

(b) *The engineer's level:* also known as tilting level it has a telescope which is not rigidly fixed to the vertical spindle (Figure 1.49). Instead, the telescope is capable of tilting slightly in the vertical plane about a point just below the telescope. This vertical movement of the telescope is made by rotating a tilting screw below the eyepiece. They have two bubbles: a *circular bubble* on the upper plate used to achieve approximate levelling by means of the three foot screws and a *telescope bubble* (tube bubble) to be levelled for each sighting by the tilting screw only. This type of levels exists in two features, the 'quickest' and 'normal' tilt levels.

Contrary to the 'normal, tilting level the 'quickset' level does not have foot screws in the levelling head. A ball-and-socket joint is provided to level the instrument quickly, but only approximately. Accurate levelling of the instrument must be completed with the tilting screw for each sighting.

Figure 1.49: *Engineer's level*

(c) *The automatic level:* automatic levels are fairly advanced than dumpy and tilting levels. They are provided with either foot screws or a ball-and-socket joint (Figure 1.50). However, they do not have a bubble tube for precise levelling. Instead, they use compensators to automatically make the line of sight horizontal once an approximate levelling has been achieved. Setting up an approximate levelling is done with the circular bubble in the same way as for a tilting level.

Figure 1.50: *Automatic level*

(d) *Tripod stand:* is an important component in any levelling process for it carries a level instrument during levelling survey. The level is mounted on a tripod stand which consists of three solid wooden or aluminum framed legs. At the lower ends, the legs are provided with pointed iron shoes for driving them on the ground during the levelling process (Figure 1.51).

Figure 1.51: *Tripod stand*

(e) *Levelling staffs:* are wooden or metallic rods, graduated into metre or feet and further smaller divisions of 10 mm intervals and marked in red, black and white for easy reading (Figure 1.52). The staffs are available in the length of 3 m to 5 m. The bottom of the levelling staff represents the zero reading. The reading given by the line of sight on a levelling staff held vertically is the vertical distance above the point on which the staff is held.

Levelling staffs may be grouped into two classes: self-reading staffs and target staffs.

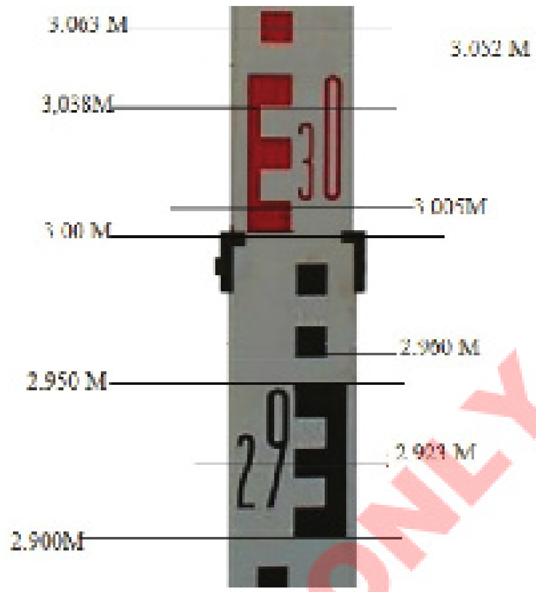


Figure 1.52: *Readings on levelling staffs*

(i) *Self-reading staff:* are those in which the readings are directly obtained by the observer through the telescope. In self-reading staff, any ordinary man can hold the staff and keep it in plumb. Self-reading staffs are of three types: the solid staff, the folding or hinged staff and the telescopic staff. *The Solid staff* are usually available in 3 m long in one length. The absence of hinge or socket on these staffs makes them more accurate in reading compared to hinged staff. However, the staffs are inconvenient to carry in the field. Use of a solid staff is generally restricted to only precise levelling work. *Folding or hinged staff* are made of well-seasoned timber with 4 m long. They consist of two portions, each being 2 m hinged together. The width and thickness of the staff is kept 75 mm and 18 mm respectively. *Telescopic* or

Sopwitch type of staff consists of three pieces: the top piece is solid 1.25 m long whereas the central piece 1.25 m and the lower piece is 1.5 m long. The central and lower pieces are hollow. The top portion slides into the central portion telescopically. When fully extended, the total length of the staff is 4 m. The upper two pieces are held by brass spring catches.

(ii) *Target staff:* is a class which consists of two ordinary rods: the upper rod, 6 ft. in length, and which slides into the lower one which is 7 ft. in length. The target which can be moved up and down is attached to the staff. The rod is graduated in feet, and its tenths and hundreds. For taking readings, the level man directs the staff man to raise or lower the target till it is bisected by the line of sight. The staff man clamps the target and takes the reading. This means that the duties of a target staff-man are as important as those of the observer and demand the services of a trained man.

(f) *Theodolite and total station:* although levels are still highly in use, it is not because they are the only equipment that can be used for levelling. Technological development has provided options to other advanced and sophisticated equipment like Theodolites and Total stations (Figure 1.53).

Figure 1.53: *(a) Electronic theodolite*

Figure 1.53: *(b) Total station*

Theodolite is an optical or electronic equipment for measuring horizontal and vertical angles or distances. Total station is an electronic instrument for measuring both horizontal and vertical angles and distances. The two equipment are used in a trigonometric levelling, which applies trigonometric relationship to determine elevation of points from measured vertical angles and horizontal or slope distances.

Types of levelling

Levelling is classified differently based on different perspectives and context. All levelling practice can be divided into direct levelling which involves all methods which take vertical distances direct from the field, and indirect levelling in which vertical distances are not measured directly in the field. Direct levelling is of two types, namely *differential levelling* and *profile levelling*.

(a) Differential levelling

Differential levelling is carried out to determine the elevation of a distant point that cannot be determined with a single set up of the instrument. It involves setting up a level several times to take reading along the route between the BM and the distant point (P). At each instrument set up, only two staff readings, a BS and an FS are observed as shown in Figure 1.54.

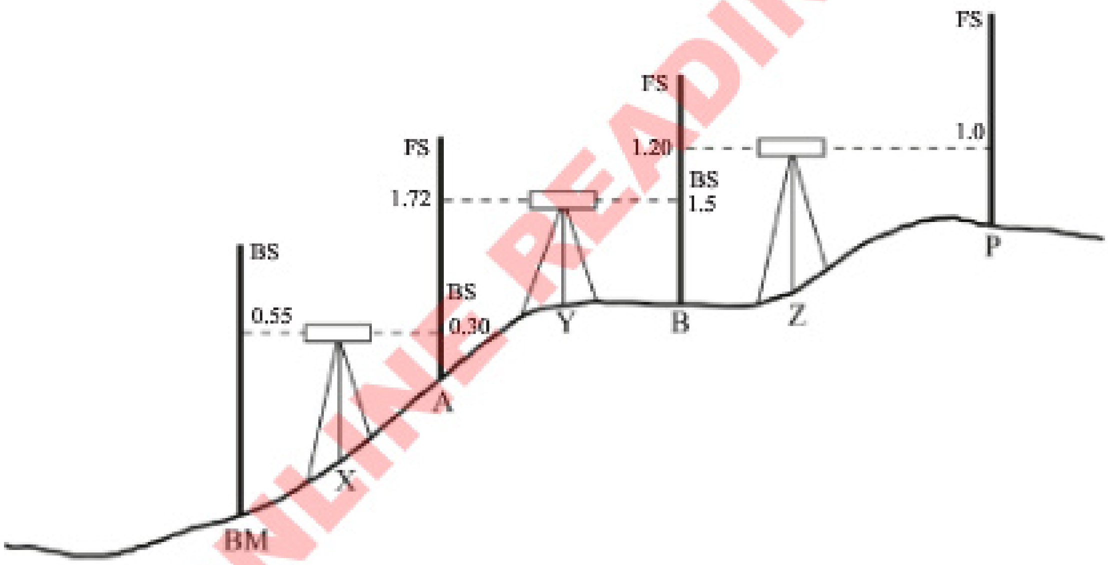


Figure 1.54: *Differential levelling*

(b) Profile levelling

Profile levelling is another category of direct levelling which determines elevations of a series of points along a line before shifting the level to another station. In this type of levelling, an instrument can determine elevation of several points between a back sight and fore sight. As such, a back sight, a fore sight and as many intermediate sights as possible are taken in profile levelling (Figure 1.55). Profile levelling is particularly considered important in drainage and terrace layout.

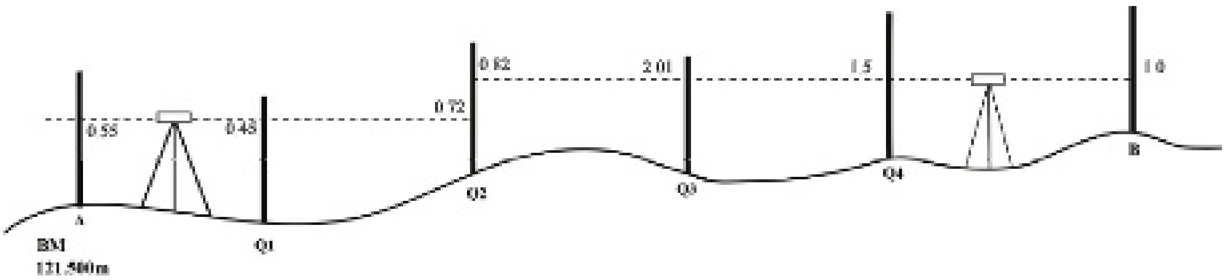


Figure 1.55: *Profile levelling*

Levelling procedures

The execution of levelling starts with the adjustments of the level instrument and followed by observation and recording of BS, IS and FS (staff reading) in level sheets.

Instrument adjustment

The instrument adjustment done in levelling is categorized into temporary adjustment and permanent adjustment.

(a) *Temporary adjustment*

These are adjustments performed at each instrument station where a level is set-up before taking any observation. Temporary adjustment involves setting up a level, levelling and eliminating parallax. The following procedures are carried out in each stage.

(i) Setting up the level: is an operation that includes fixing the instrument on the tripod stand and levelling the instrument approximately by leg adjustment. To fix the instrument on tripod stand, tripod legs are well spread on the ground to place a tripod's head at a nearby level and at a convenient height. The level is mounted and fixed on the tripod and the foot screws are brought to the centre of their run.

(ii) Levelling is done with the help of foot screws and bubbles. The purpose of levelling is to make the vertical axis truly vertical. The method of levelling depends upon whether there are three-foot screws or four-foot screws. In all modern instruments, three-foot screws are provided and only procedures for levelling instruments with three-foot screws are explained. In the first step, a tubular bubble is aligned parallel to any two-foot screws which are then simultaneously turned inward or outward to bring the bubble to the centre. Then, the tubular bubble is aligned perpendicular to these two foot screws and a third screw is turned to bring the bubble to the centre. The tubular bubble is turned to different positions to check whether the bubble remains central. When the bubble is central, the level is levelled, otherwise permanent adjustment is required.

(iii) Elimination of parallax involves two operations which are focusing on the eye piece and focusing on the objective. To *focus on the eye-piece*, first direct the telescope either towards the sky or hold a sheet of white paper in front of the objective. Then, move the eye-piece in or out till the crosshairs appear distinct and very dark. In some levels, the eye-piece is graduated and numbered. Once the eye-piece is focused, the observer may note this position to save much of his time at other settings.

The objective is focused to adjust the visibility of a staff through a telescope. To focus on the objective, direct the telescope towards the levelling staff to see the staff. If the staff is not seen from the telescopic level, turn the focusing screw till the staff image appears clear and sharp. The image of the staff should be formed on the plane of crosshairs.

(b) *Permanent adjustment*

Contrary to temporary adjustment, permanent adjustment can be carried out when the device has major technical problems. Two types of permanent adjustments are usually carried out in levelling: adjustment of bubble tube error and collimation error. The bubble tube error happens when the vertical axis of a level is not truly vertical after bringing the bubble to the centre. The collimation error happens when the line of sight is not horizontal after bringing the bubble to the centre.

Field procedures and field data booking

Field levelling procedures involve setting up the instrument as described in temporary adjustment, reading vertical distances on the levelling staff and recording them on field notebooks.

Reading vertical distances

To take the staff readings, the following procedures are followed:

(i) The level is set up at a convenient position, such as X and the level staff is placed over the benchmark (BM), such as the BM of a reduced level of 100 m in Figure 1.56. Then, the first reading, called back sight (BS), is taken at the BM. Let its value be 1.82 m.

(ii) The staff is now moved to points A and B in turn and readings, called intermediate sights (IS), are taken. Let their values be 1.0 m and 0.6 m. The staff is moved from station B to C and the last reading, let its value be 0.25 m, called foresight (FS), is taken with the first set up of the instrument.

(iii) After taking the last reading in the first set up of the instrument, the level is moved to the second position, say Y. Then, the staff held at station C is turned towards station Y and a back sight reading, let its value be 1.94 m, is taken at it as shown in Figure 1.56. The staff is moved from station C to D and the last reading, called foresight (FS), is taken before the instrument is shifted again, or the levelling observation stops. In Figure 1.56, BM is a benchmark, A and B are intermediate stations, C and D are change points, E is the last station, and X, Y and Z are instrument stations.

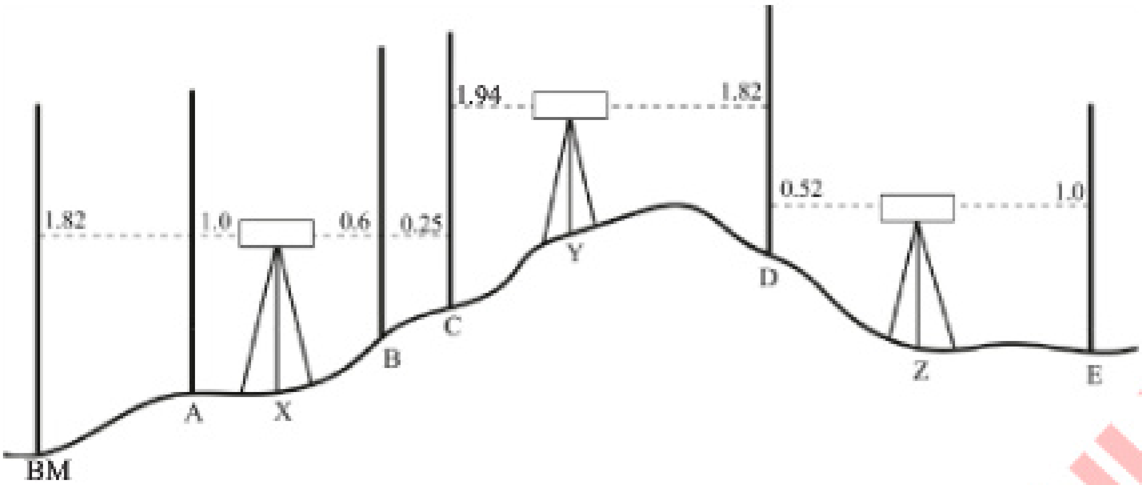


Figure 1.56: *Levelling procedures*

Recording staff reading

The staff readings are then recorded on a field notebook and reduced using the rise and fall method or the height of collimation method.

Rise and fall method

In the rise and fall method, the amount by which a point is above or below another point is determined by subtracting each staff reading, the IS or FS from the preceding staff reading, which could be the BS or IS. The method uses a table of eight columns, namely Station, BS, IS, FS, Rise, Fall, RL and Remarks. At each row, staff readings and reduced level at a particular station are recorded. The following procedures are followed in Rise and Fall method:

(i) In the first row, record the reading taken at the first station, BM. The station identifier is recorded in the first column, the BS in the second column and the RL in the seventh column. Remark is provided in the last column as shown in Table 1.3.

(ii) In the second row, record the station identifier, A and the IS in the third column.

(iii) Subtract staff reading at A (IS) from sight reading at BM (BS). If the difference is positive, point A is relatively above BM, meaning there is a rise in ground surface from BM to A. Record the difference in the fifth column called Rise. If the difference is negative, point A is relatively below BM, meaning there is a fall in ground surface from BM to A. Thus, the difference should be recorded in the sixth column, called Fall. The negative sign should be ignored when recording Fall values, that is, only magnitude values should be recorded.

(iv) Calculate the RL of station A by adding the Rise to or subtracting the Fall from the RL of the BM. In this case, a Rise at A is added to the RL of the BM and recorded in the seventh column. Repeat the procedures (i) to (iv) for stations B, C, D and E (see Table 1.3).

(v) At the end of the table, arithmetic check must be shown. The check is given by:

$\Sigma BS - \Sigma FS = \Sigma(\text{Rises}) - \Sigma(\text{Falls}) = RL_{LAST} - RL_{FIRST}$

Table 1.3: *Rise and fall method*

Station	BS (m)	IS (m)	FS (m)	Rise (m)	Fall (m)	RL (m)	Remarks
BM	1.82					100.00	Benchmark
A		1.00		0.82		100.82	
B		0.60		0.40		101.22	
C	1.94		0.25	0.35		101.57	Change point
D	0.52		1.82	0.12		101.69	Change point
E			1.00		0.48	101.21	Last station

$\Sigma BS = 4.28$ m

$\Sigma FS = 3.07$ m

Σ (Rises) = 1.69 m

Σ(Falls) = 0.48 m

RL of the last station (RL_{LAST}) = 101.21 m

RL of the first station (RL_{FIRST}) = 100.00 m

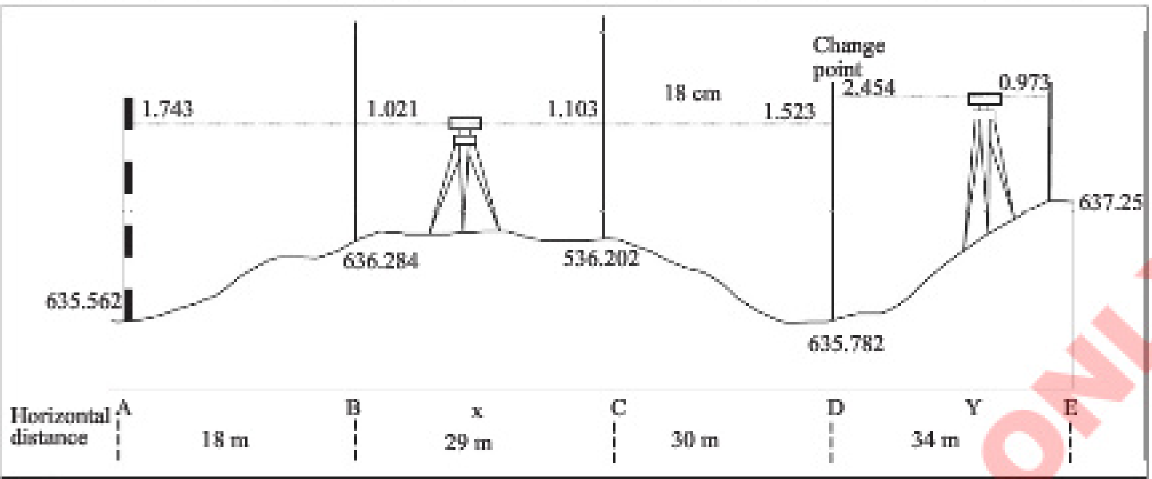
Since $\Sigma BS - \Sigma FS = \Sigma(\text{Rises}) - \Sigma(\text{Falls}) = RL_{LAST} - RL_{FIRST}$

4.28m − 3.07 = 1.21m, 1.69m − 0.48m = 1.21m, 101.21m − 100.00m = 1.21m

Therefore, recording and reduction of levelling was correctly done.

Example

Record and reduce levelling data in Figure 1.57 using Rise and Fall method.



The staff reading in Figure 1.57 are recorded and reduced as shown in Table 1.4.

Table 1.4: *Rise and Fall method for a profile levelling in Figure 1.57*

Station	BS	IS	FS	Rise	Fall	RL	Remark
A	1.743					635.562	Benchmark
B		1.021		0.722		636.284	B
C		1.103			0.082	636.202	C
D	2.454		1.523		0.42	635.782	Change point
E			0.973	1.481		637.263	Last station

$\Sigma BS = 4.197$ m

$\Sigma FS = 2.496$ m

$\Sigma BS - \Sigma FS = 4.197 \text{ m} - 2.496 \text{ m} = 1.701$ m

$\Sigma(\text{Rises}) = 2.203$ m

$\Sigma(\text{Falls}) = 0.502$ m

$\Sigma(\text{Rises}) - \Sigma(\text{Falls}) = 2.203 \text{ m} - 0.502 \text{ m} = 1.701$ m

RL of last station (RL_{LAST}) = 637. 263 m

RL of the first station (RL_{FIRST}) = 635.562 m

$RL_{LAST} - RL_{FIRST} = 637.263 \text{ m} - 635.562 \text{ m} = 1.701$ m

Since $\Sigma BS - \Sigma FS = \Sigma(\text{Rises}) - \Sigma(\text{Falls}) = RL_{LAST} - RL_{FIRST} = 1.701$,

Therefore, the recording and reduction of levelling was correctly done.

Height of collimation method

In height of collimation method, the height of collimation (HC) is determined at each instrument set up by adding the BS to the respective RL. The method uses a table of seven columns, namely Station, BS, IS, FS, HC, RL and Remarks. At each row, staff readings and reduced level at a particular station are recorded.

The procedures for height of collimation method are illustrated using data in Figure 1.55 as explained below:

(i) In the first row, record the reading taken at the first station, say BM. The station identifier is recorded in the first column, the BS in the second column and the RL in the seventh column. Add a staff reading at BM (BS) to the RL of the BM to get the height of collimation (HC) for the first instrument set up, and record it in the fifth column. In the last column, a remark is provided (Table 1.5).

HC at first set up = BS at BM + RL of station BM

(ii) In the second row, record a staff reading taken at Q1 (IS) in the third column. Then, subtract staff reading at Q1 (IS) from the HC of the first setup of instrument to get the RL of station Q1 and record it in the sixth column. Continue determining and recording RL at all stations observed in the first set up (Table 1.5).

RL at A = HC at first set up – IS at Q1

RL at Q2 = HC at first set up – FS at Q2

(iii) Add a BS reading taken at B in the second set up of the instrument to the RL of station Q2 to get the second height of collimation (HC) and record it in the fifth column as shown in Table 1.5.

HC at second set up = BS at Q2 + RL of station B

(iv) In the fourth, fifth and sixth rows, subtract staff readings taken at stations Q3, Q4 and B from the HC of the second set up of the instrument to get their respective RL and record them in the sixth column.

RL at Q3 = HC at second set up – IS at Q3

RL at Q4 = HC at second set up – IS at Q4

RL at B = HC at second set up – IS at B

(v) Repeat the procedures (c) to (d) for any instrument set up that follows.

(vi) At the end of the table, arithmetic check must be shown. The check for height of collimation method is given as:

$\Sigma BS - \Sigma FS = RL_{LAST} - RL_{FIRST}$.

Table 1.5: *Height of Collimation method for a profile levelling*

Station	BS (m)	IS (m)	FS (m)	HC (m)	RL (m)	Remark
BM(A)	0.55			122.05	121.50	Benchmark
Q1		0.45			121.60	
Q2	1.82		1.72	122.15	120.33	Change point
Q3		2.01			120.14	
Q4		1.50			120.65	
B			1.00		121.15	Last station

$\Sigma BS = 2.37$ m

$\Sigma FS = 2.72$ m

$\Sigma BS - \Sigma FS = -0.35$ m

RL of last station (RL_{LAST}) = 121.15 m

RL of the first station (RL_{FIRST}) = 121.50 m

$RL_{LAST} - RL_{FIRST} = -0.35$ m

Since $\Sigma BS - \Sigma FS = RL_{LAST} - RL_{FIRST} = -0.35$ m

Therefore, the recording and reduction of levelling was correctly done.

Remember:

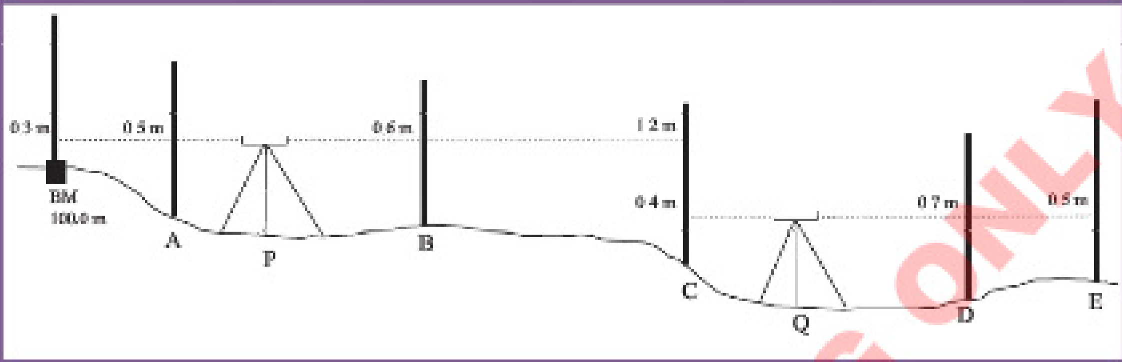
(i) Only one staff reading is recorded in each row, except at a change point. In Table 1.5 for instance, one staff reading is recorded at the first, second, fourth and fifth rows, while two staff readings (BS and FS) taken at change point (CP) Q2 are recorded in the third row.

(ii) In Height of instrument or Height of Collimation, the HC is recorded at a BM(A) and every change point. In Table 1.5 for instance, HC is recorded at BM(A) change point (CP) Q2.

(iii) In rise and fall method, only magnitude values of rise and fall are recorded; their associated algebraic signs are not written.

Activity 1.6

1. Identify intermediate stations and change points in a profile levelling shown in the given figure.
2. In the following figure, record the staff readings and reduce the elevation stations A to E using: (a) rise and fall method (b) height of collimation method.



Staff reading along a profile levelling

Application of levelling

Levelling knowledge and skills is relevant in our daily life. In addition to determining the difference in levels between two points, the main applications of levelling are in contouring, preparation of longitudinal and cross-sectional profiles and setting out of levels in construction works.

Contouring

Contouring is the process of creating contours. Contours are imaginary lines connecting points of equal elevation. Contouring can be done using direct method or indirect method.

Direct method of contouring

In the direct method of contouring, points defining a contour line are pegged out on the ground and their horizontal positions determined. The contouring method involves the following procedures:

(i) A level is set at a convenient position in the area and a BS reading is taken at an appropriate benchmark.

(ii) The height of collimation is found and the required staff reading for a contour line is calculated. The required staff reading is determined by subtracting a contour from the height of collimation. Staff reading (IS or FS) = HC – contour value.

(iii) The instrument man asks the staff man to move up or down in the area till the required staff reading is found. In Figure 1.58, a staff reading of 1.3 m is needed to mark a contour of 101.5 m. The staff was first held at point 1 and its reading was higher than 1.3 m. Thus, it was moved to points of higher elevations until a staff reading of 1.3 m was taken.

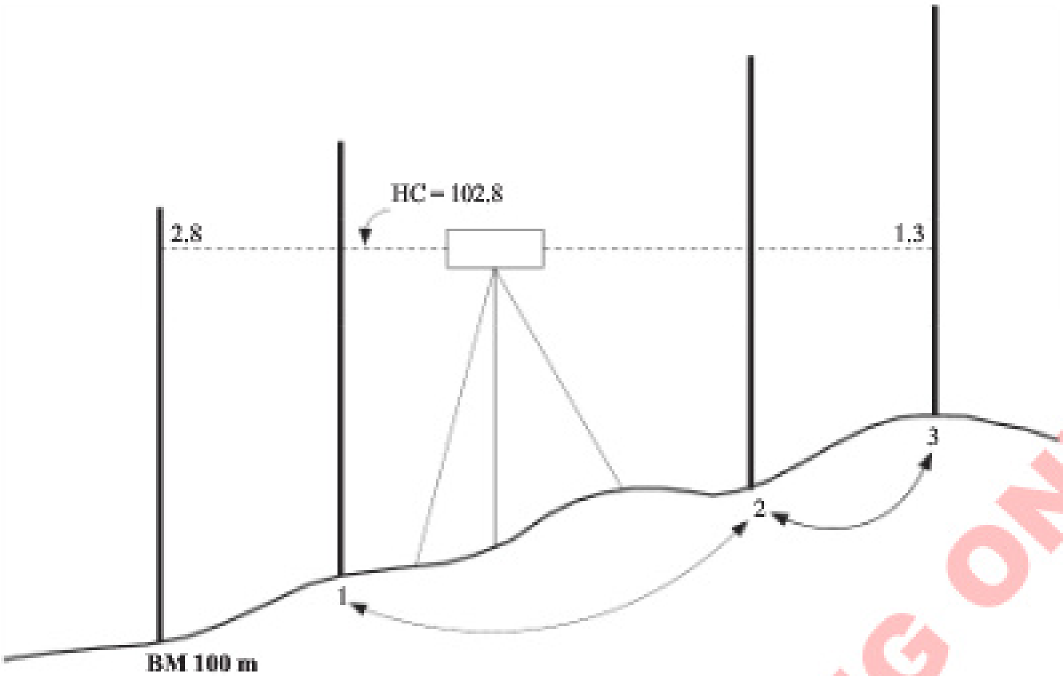


Figure 1.58: *Direct contouring*

Then, the surveyor determines the horizontal coordinates of that point using chain surveying, compass surveying, plane table surveying or other advanced surveying. The method is very accurate but slow and tedious.

Activity 1.7

Identify any permanent mark and assume it to be a benchmark of 103.625 m, then:

(a) Determine the staff reading at points where the contour of 105 m passes.

(b) Mark on the ground any 10 points where the contour of 105 m passes.

Indirect contouring

In the indirect contouring method, staff readings are taken at some selected points and their levels are reduced. That is, the horizontal position is established first and then the levels of those points are found. After locating the points on the plan, reduced levels are marked and contour lines are interpolated between the selected points. During the interpolation it is assumed that the ground is uniform between any two spot heights. The indirect method is further classified into grid and radiation methods based on the approach used to select points for staff reading.

Grid method

Grid method is best suited to gently sloping undulating land and fairly small areas. In this method, the area to be surveyed is divided into grid or series of squares. The grid corners are marked on the ground and their spot heights are determined through levelling. The grid is plotted to the scale and the spot heights of grid corners are entered. The contours of desired values are and located by interpolation as shown in Figure 1.59.

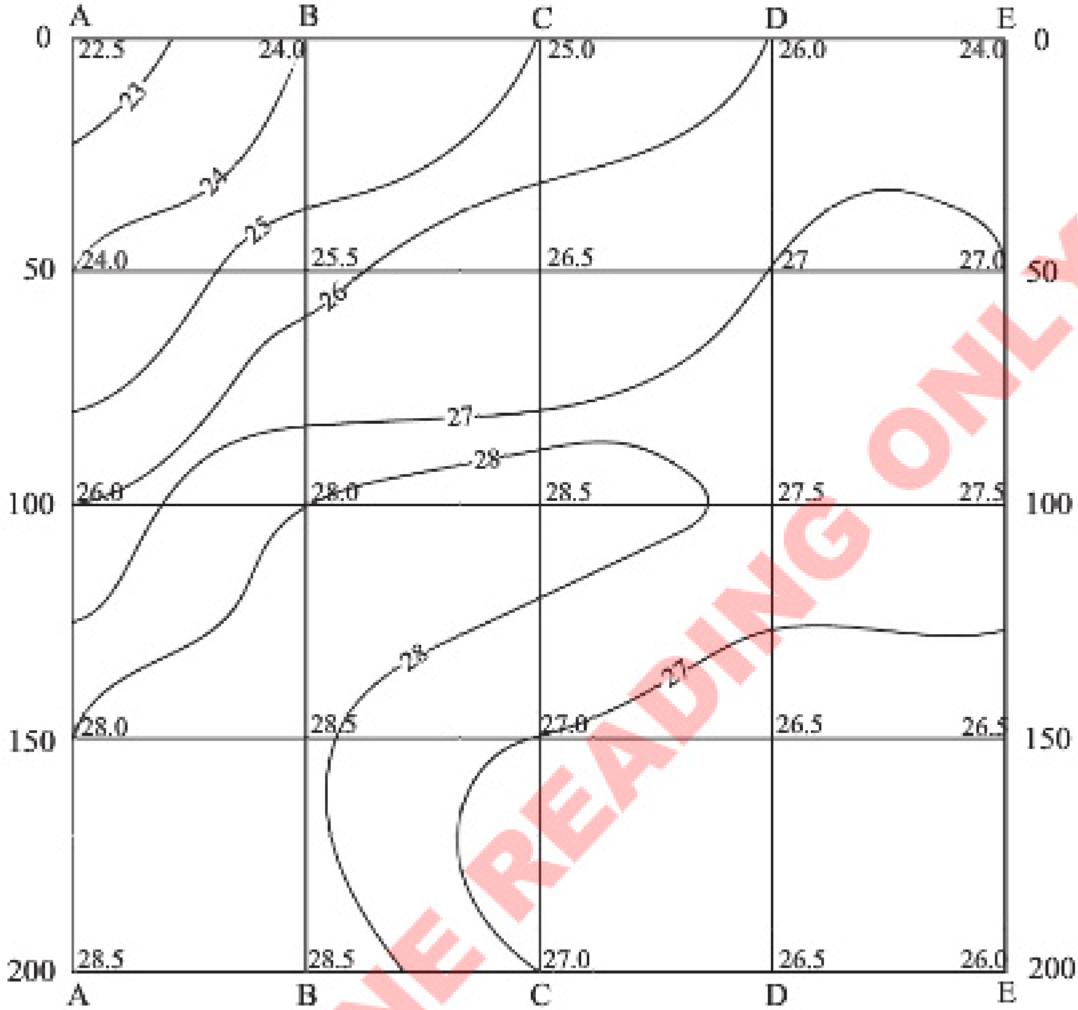


Figure 1.59: *Grid method of indirect contouring*

Radiation method

Radiation method is useful for areas located in small hills. The method establishes a central position on a hill and sets out radiating lines using the prismatic compass, theodolite or total station. Points are then marked on ground at a regular interval along the radiating line and their spot heights are determined through levelling. The radiating lines and the marked points are plotted to scale and the spot heights of the marked stations are entered. The contours of the desired values are then located by interpolation as shown in Figure 1.60.

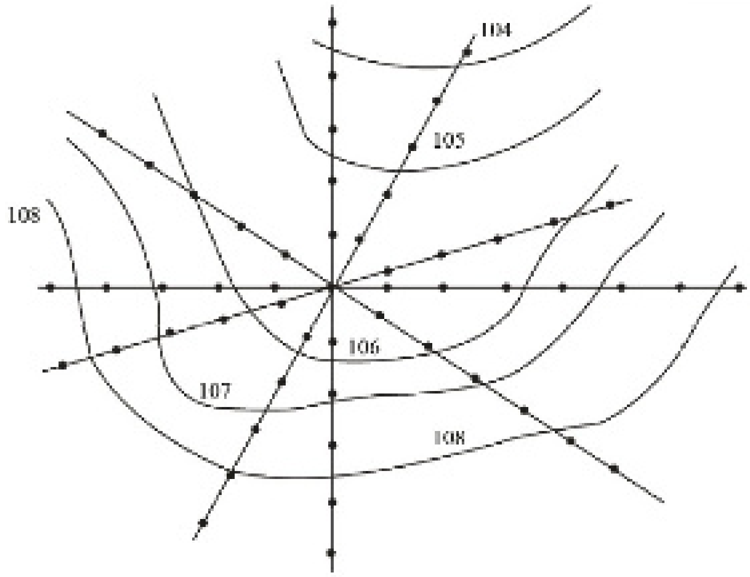


Figure 1.60: *Radiation method of indirect contouring*

Errors in levelling

Errors in levelling exist and can be grouped into Personal errors (due to natural causes) and instrumental errors. Personal errors can include those resulting from sighting problems, manipulation errors, error in reading the staff, those from recording and computation. Sighting errors can be a result of visual impairment or failure of a tool's cross hair to coincide with the staff graduations. The later could be a result of either long sights or coarseness of the crosshairs and the staff. In some cases, natural changes of atmospheric conditions during the practice, such as the presence of mist or fog, can impair visibility of the staff from the instrument man, hence errors. This category of errors can be accidental and compensative.

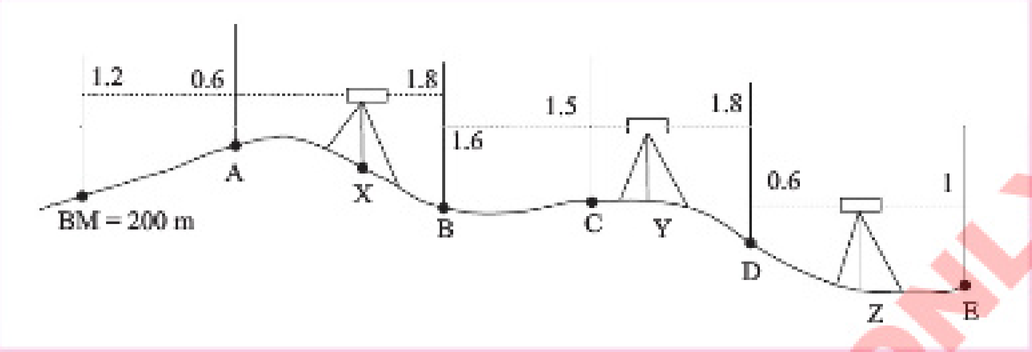
Manipulation errors are mistakes or blunders as other surveyor call them. In most cases, they originate from failed adherence to surveying ethics. They may be caused by careless setting up of a level: the presence of parallax (the imperfect focusing on eyepiece and objective) and imperfect levelling of an instrument. Too much trust over your experiences or assumptions and instrument's verticality causes an error of no-verticality of the staff. The absence of a staff bubble plate attached to a staff causes difficulty in holding of the staff verticality. Other equally defective causes for errors are incorrect reading, recording and computation of the staff reading.

Activity 1.8

Choose an area of 200 m by 200 m and divide it into grids of 50 m, then perform levelling to determine elevation of each grid intersection and prepare the contour map of the surveyed map.

Exercise 1.3

1. A profile levelling was carried out to determine elevations of stations A, B, C, D, and E as shown in the following figure.



   (a) Identify intermediate stations (IS) and change points (CP).

   (b) Record staff readings and determine the reduced levels of stations A, B, C, D, and E using:

      (i) Rise and fall method.

      (ii) Height of collimation method.

   (c) Perform the arithmetic checks for the two methods applied in (b) above.

2. Complete by filling the following table using height of collimation method.

Station	BS	IS	FS	HC	RL	Remarks
BM	1.82				500	Benchmark
A		1.68				
B		1.42				
C	1.40		0.68			
D		1.48				
E		1.62				
F			1.84			
	ΣBS =		ΣFS =			

3. Explain ways in which levelling survey is significant in the day to day life.

Revision exercise 1

1. (a) Differentiate:
   (i) Vertical line from vertical control.
   (ii) Horizontal line from horizontal plane.
   (iii) Level surface from level line
   (iv) Mean sea level from bench mark.

   (b) Identify the sources of errors in levelling.

2. The following consecutive readings were taken with a level and a 4m levelling staff on a continuously sloping ground at a common interval of 30 m. 0.855 on A, 1.545, 2.335, 3.115, 3.825, 0.455, 1.380, 2.055, 2.855, 3.455, 0.585, 1.015, 1.850, 2.755, and 3.845 on B. The position of the level was changed after the 5th and 10th staff reading.
   (a) Make the entries in a level book and apply the usual check.
   (b) Determine the gradient of AB.

3. A water pipe is to be laid between 2 points at the slope of 1:5. Explain how you would determine the slope of the ground between the two points using surveying.

4. Describe the criteria you would use in choice of surveying method to plot area with obstacles.

5. Choosing a compass survey of your choice, explain the instrument you will mobilize and give reasons for each.

6. Describe the instruments used in differential levelling.

7. Explain personal errors in levelling.

8. Suggest six ways by which errors can be minimized in levelling survey.

9. A differential levelling loop began and closed on BM Tree (elevation 654.07 ft). The plus sight and minus sight distances were kept approximately equal. Readings (in feet) listed in the order taken are 5.06 (+) on BM Tree, 8.99 (–S) and 7.33 (+S) on TP1, 2.52 (–S) and 4.85 (+S) on BM X, 3.61 (–S) and 5.52 (+S) on TP2, and 7.60 (–S) on BM Tree. Prepare, check, and adjust the notes.

10. A differential levelling circuit began on BM Hydrant (elevation 1823.65 ft) and closed on BM Rock (elevation 1841.71 ft). The plus sight and minus sight distances were kept approximately equal. Readings (in feet) given in the order taken are 8.04 (+S) on BM Hydrant, 5.63 (–S) and 6.98 (+S) on TP1, 2.11 (–S) and 9.05 (+S) on BM 1, 3.88 (–S) and 5.55 (+) on BM 2, 5.75 (–S) and 10.44 (+S) on TP2, and 4.68 (–S) on BM Rock. Prepare, check, and adjust the notes.

11. Classify survey on the basis of instruments and describe all necessary equipment for field work involving one of them.

12. A crossed traverse is conducted with five stations A, B, C, D, and E in anticlockwise direction to form

the pentagon. If FB of AB is 400, find the FB of other sides.

13. Describe methods of plotting the compass traverse.

14. (a) How do closing errors occur in traverse?

    (b) By using the Bowditch's rule, explain procedures of adjusting the mis-closure.

15. (a) What is a three-point problem?

    (b) By using the Bessel's method, describe how a three-point problem can be resolved.

16. (a) What is plane table orientation?

    (b) Explain methods of orienting the plane table.

17. (a) Describe plane tabling procedural by intersection and resection.

    (b) Describe plane tabling procedural by radiation and traversing methods.

18. (a) In which circumstances is differential levelling recommended?

    (b) Differentiate between height of instrument and the rise-fall method.

19. Jamasule is studying at Karume Institute of Science, Faculty of Engineering. He was assigned to conduct a survey around a sloped area in his college environment.

    (a) Identify an appropriate surveying technique which might be used.

    (b) Describe four equipment which can be used in the surveying technique named in (a) above.

    (c) Explain four uses of the surveying techniques named in (a) above.

20. The magnetic bearing of the line CD is S 30° 15' W. find the true bearing if the declination is 20° 15' E.

Chapter Two

Geographical Research

Introduction

Geography as a subject which is often studied theoretically in the classroom, can be validated through the real-life field experiences using sense organs. In this chapter, you will learn about sources of scientific knowledge acquisition, types and importance of research, research problem formulation, literature review, hypotheses or questions formulation and process of selecting relevant research designs. Furthermore, you will learn about sample and sampling designs, methods and tools for data collection and reporting. The competences developed will enable you to identify the existing gaps in geographical knowledge and practices, and conduct geographical research.

Think about

Gathering information of quest to discover the world.

Activity 2.1

Read the geographical research books from various sources including library and internet then answer the following question:

(a) (i) What does geographical research mean?
(ii) In which ways do you think geographical research is important in your daily life?

(b) By giving reasons, explain the appropriate time for writing:
(i) Geographical research proposal
(ii) Geographical research report

(c) What is the relationship between a research proposal and a research report?

Conceptualising geographical research

Research refers to a search for knowledge in order to discover the truth. It is done systematically on a particular topic or issue for explaining, describing, or predicting it. It involves physical data collection from the real-life environment. Before conducting a research, there are important things to consider. These include identification of a research problem, selection of an appropriate research site, identifying methods and preparing tools for data collection. Having clues on the attitude of the respondents and carrying out a pilot study are also important.

Field is an area or environment where the research is being carried out. Thus, field research is normally carried out in a natural setting rather than structured environment like laboratories and classrooms. It is the science of observing, evaluating, selecting and reporting on geographical phenomena from a specific area. Field research allows the researcher to interact with the natural environment through observations and conversations to elicit information concerning the data sought to answer the research questions.

A number of methods and techniques are used in field studies. Some of the commonly used methods and techniques include observation of events in the natural settings, studying of information from the existing records (archival research), and field experiments (experiments carried out in natural settings) to understand relations among variables. Furthermore, field research can use surveys for collecting data from people's actions, thoughts, and behaviours by asking questions related to their natural settings. The process of conducting field research needs good preparation from budgeting, time schedule and well set research tools for data collection.

Criteria of a good geographical research

A common characteristic to all types of research is application of scientific method. Research being a process of collecting, organizing, analysing and interpreting information to answer pre-determined questions should adhere to the established criteria. Thus, good research has to be:

Systematic: meaning that any research should be carried out in a well-structured framework with a clear step by step process in attaining the solutions or conclusions. In this case, research starts by defining the research problem followed by a review of literature, stating research questions or formulating hypothesis, selecting a research design, selecting the study area, collecting data, organizing data, analysing data to answer questions or to test hypotheses, and finally writing a report.

Logical: this means that any research should be guided by the rules of appropriate organisation and flow of ideas throughout the research process. This mainly focuses on inductive and deductive reasoning approaches which are compulsory in decision making processes.

Empirical: meaning that a research should basically be related to one or more aspects of real-life situations or conditions from which data are gathered in achieving valid research results. In other words, conclusions are being drawn based on true evidences collected through life experiences and repeated observations.

Replicable: this means that research methods and findings of a given study should be stated in such a way that they allow to be verified or tested by other researchers. In this regard, a research is thought to be replicable if independent researcher (s) elsewhere will apply the same methods used by the previous researcher and arrive to the same conclusion made in the previous study.

Cumulative: knowledge is accumulated as a result of regular studies, in the sense that new studies should be built over what has already been done on the subject matter of interest. Therefore, new knowledge adds up to the existing one.

Theory driven: meaning that, theories connect researchers with the existing knowledge as they offer a conceptual model from which data are collected. Generally, there is no research without a theory. It may start with theory or end-up generating a new theory.

Objectivity: this means that any research should be strongly related to the research problem and it should rely on observations from actual studies which can be either cross-sectional or longitudinal. Similarly, conclusions should be drawn from the available set of evidence with the aim of avoiding biasness.

Generalisability: research as a scientific process allows conclusions to be generalised and universal. Generalisation is made from a sample to the population.

Clarity: scientific research should be precise and with good explanation.

Rigorous: research should ensure that the methods used in answering the research questions are relevant and justifiable.

Sources of knowledge acquisition and approaches

Throughout our lifetime we have accumulated a body of knowledge. The curiosity to know the environment and the need to improve our life is natural to human beings. Humans have used numerous methods and sources to acquire knowledge. Knowledge acquisition has been mainly from the authority from which human being learns. Some of these authorities are teachers, parents, leaders at work or any expert who may provide the needed knowledge. Such authorities may be a source of knowledge, experience or both. The authorities also can be books, newspapers, dictionary, encyclopedia, journal articles or websites. Knowledge is also obtained from our traditions where we as human beings accept many traditions of our forefathers or culture. For example, aspects such as food, dress, religion, home remedies, discipline, ways of behaving and others can be learned from traditions.

Furthermore, knowledge can be acquired through experiences. That is, through education, own experiences on problem solving or understanding of a phenomenon. These are the most common sources of gaining experience which we are familiar with and are fundamental sources of knowledge. In sharpening comprehension and accepting learning through these sources, several approaches are used. Among them are:

(a) Empiricism: this is based on our senses. For example, through hearing and seeing, we can associate some phenomena like sounds and their sources. Through senses we can compare objects, phenomena or events. Hence, our senses help us to study and understand relationships between various concepts. For example, we can associate changes/variations in temperature with climate change by observing temperature trends for over 30 years.

(b) Rationalism: this relies on mental reflections on ideas rather than materials. The logical links between two or more ideas can lead us into accepting those ideas. For example, we may reason that appropriate farm management is expected to improve crop yield per piece of land.

(c) Fideism: this relies on beliefs, emotions and reactions. We acquire knowledge from religion by believing through the teachings provided by our religious leaders rather than the use of our own senses or need for logical proof.

Activity 2.2

Search for information from various sources about sources of knowledge and acquisition then:

(a) Classify the common sources of knowledge acquisition.

(b) Discuss on how the knowledge acquired is verified and accepted to be true.

(c) To what extent can such means of verification in (b) be trusted?

Exercise 2.1

1. To what extent is research a science?
2. 'Knowledge acquisition is normally intrinsic in nature.' Explain.
3. What are the necessary preparations for conducting a field research?

The purpose of doing geographical research

Normally, research strives to answer questions through the use of scientific procedures. The aim of a researcher is to generate new knowledge, adding to and validating the existing body of knowledge.

Though there are many varieties of research motives, the following research purposes may suffice. Firstly, to gain familiarity with the researched phenomenon or acquire new insights. Secondly, to depict accurately the characteristics or nature of a particular individual, situation or a group under the study. Thirdly, to determine the frequency or recurrence of some subjects, and fourthly, to test hypothesis or causal relationship between variables in order to develop theories and criticisms.

Types of geographical research

Search for new knowledge has resulted into multiplication of researches. The emerged variety of researches can be classified into four main categories basing on the nature of information sought, utility of content, the research approach employed and objective perspectives.

On the basis of the nature of information sought research can be grouped into two categories namely, *qualitative research* and *quantitative research*. Qualitative research is a study which deals with non-numerical data. This is a form of field research which is carried out in a naturalistic setting that mainly generates qualitative data through observations and interviews. Qualitative research aims at describing the characteristics of samples.

Conversely, quantitative research is the study which uses numerical data to address behaviour and attitude. It is used when quantitative data are sought after. It is mainly concerned with making inferences from randomly selected samples to a larger population. However, with time, there has been a growing need for integrating both qualitative and quantitative data in order to cross-check the results obtained from the combined methods and this has given rise to *mixed methods research*. Recently, most of the researchers have found it logical to opt for mixed methods research in answering research questions.

Basing on the utility of the content or nature of the subject matter, research streams into two categories. The first category is *basic research* which is also known as fundamental research, pure or theoretical research. The aim of these researches are to find out the basic truth or principles. Normally, the generated findings in this case are universal, so is the utility. These researches are generally guided by theories such, Newton's law of universal gravitation, and Newton's laws of motion.

The second category of research basing on the utility of content or nature of subject matter is *experimental or applied research or action research*. This is concerned with finding new applications of scientific knowledge to solve scientific problems such as development of new system. Normally, the findings from this research has a confined utility to the individuals who benefit from them.

With regards to the research approach applied, there are two main categories namely, *longitudinal research and cross-sectional research*. Longitudinal research deals with studying the same site at varying intervals of time in order to establish change. This is exemplified in historical and case study research. Cross-sectional is concerned with collecting data at one point in time from predetermined sites and individuals.

On objective perspectives criteria, we have a descriptive research. *Descriptive research* is confined on explaining the conditions of variables based on the situation at which data were taken. This type of research is further subdivided into observational, survey and case study researches. While *observational research* is concerned with collecting data in a natural condition of the research participants or objects, a *case study* deals with an in-depth study confined to a single participant or group. Survey research on its side deals with the study of the present phenomena and it is quantitative in nature.

Other types based on objective perspectives are correlational, explanatory and exploratory research. *Correlational research* is devoted to explaining or discovering the extent at which two or more variables have associations or interdependence whereas *explanatory research* focuses on giving reasons and mechanisms on the existing relationships between two aspects or phenomena that are studied. The last category is *exploratory research* which deals with investigating a situation where little is understood in the body of knowledge.

Activity 2.3

1. Use various sources to search and read on research then:

   Discuss a research scenario under which each of these types of research would be most appropriate and write down the information you have obtained.
   (i) Explanatory research
   (ii) Descriptive research
   (iii) Exploratory research
   (iv) Experimental research
   (v) Applied research

Exercise 2.2

1. Explain the role of the research purpose in determining the dimensions of the body of knowledge.
2. Comment on the statement that "Knowing a research type is one of the ways towards solving a research problem."

Importance of geographical research

Most of the research that is done aim at solving practical or theoretical problems existing in the society. Based on such view, research provides us with the basis for decision-making and planning for government policies formulation, implementation, monitoring and evaluation. Specifically, research is important in the following areas.

Firstly, in addressing a research problem which may be an existing issue or phenomenon that requires solutions based on scientific studies. Such issues may emerge anywhere in the society and fields. Provided the problems require scientific analysis, our interests are to get an understanding of the problems and propose possible solutions.

Secondly, research is one of the most potential sources of knowledge that provides us with guidelines on how to verify knowledge which we acquire. Thirdly, researches directed to the existing theories and concepts are helpful in understanding such theories and finding out ways to utilize them.

Fourthly, research plays part as a basis for governments' planning and decision-making. This demand enhances the emphasis that researchers should always strive for valid and reliable researches for backing up the decisions. Research provides a basis for many government policies in a variety of dimensions. For example, research on the effectiveness of strategies to empower community adaptation to climate change and dynamics of the crop farming practices can improve decision making in the formulation of environmental and natural resources management policies.

Fifthly, research can benefit a number of sectors in improving practices such as in production, markets of goods and services. In the environmental sector, it can shed light on the environmental management options like clean production for sustainable development. Sixth, research can lead to identification and characterisation of brand-new goods and services. Through research, we can also widen our understanding of various phenomena such as climate change, its effects and suggested measures to be taken for either mitigation or adaptation.

Sixthy, reseach is important in broadening our understanding on crucial determinants of our well being. A good example is the understanding of weather information and climate behaviour. Weather information is needed on a daily basis in the course of planning from the national to the individual level. For example, farmers need it for planning their farming activities for good harvest. Also, weather can be used in prediction and forecasts of extremely violent weather events that may require some measures to reduce their effects. Similarly, climate is a determinant of life on Earth, particularly the distribution of resources and determination of activities. Following this, statistical information is significant in facilitating the making of informed decisions, hence contributing to the development in different spheres of life.

Exercise 2.3

1. Describe roles of research in our daily life.
2. Discuss how the government of Tanzania can use research as a basis for planning and decision making.
3. Choose a type of research and explain how can be useful in addressing a geographical challenge in your area.

Geographical research proposal and report writing

Field research is normally preceded by a research proposal and finalised by report writing. A proposal functions as a 'question' in which the researcher demonstrates the existence of a phenomenon (research problem) that serves as a research question, whereas a research report functions as an 'answer' in which the researcher demonstrates a solution to the previously posed question. However, the answers to the research can be partial or complete, depending on the attention paid to the criteria for good geographical research, as well as competence in academic research writing. The research proposal and report share three major components: preliminary pages, main text, and appendices. However, a research proposal differs from a research report.

The distinction between a research proposal and a research report can be summarized in five categories: purpose, timing, content, length and detail, and audience. Depending on the purpose, a proposal serves as a plan for research, typically written before beginning a research project to obtain research approval and funding, whereas a research report is a summary of the research that includes analysis and findings.

In terms of timing, the proposal is typically written before conducting research, whereas the research report is written after the field research is completed. In the case of content, research proposal is a summary of what will be done in the proposed research, why it is important to be researched, how it will be researched, and the estimated time and cost. On the other hand, a research report is a summary that aims to inform about what was carried out, how it was carried out, what were the results and what the results mean.

A research report includes more information, analysis, presentation, interpretation, discussions, conclusions, and recommendations. Regarding the audience, a proposal is typically written for approval to carry out research whereas a research report can be useful to academics, the government, policymakers, and other interested readers to inform them of the research results and findings.

Geographical research proposal

A research proposal is a document written by a researcher that gives detailed explanations on how the researcher plans to do the research. It is a plan suggesting what the researcher intends to do, means of doing it, and proposes resources to accomplish the plan. It is a descriptive plan of action, which is to be followed in carrying out a particular research. The proposal is like an outline of the whole research process that gives a reader the summary of the information discussed in the plan.

Preparation of research proposal is needed since it facilitates the planning of different research operations, hence making the research as efficient as possible, yielding adequate information with minimal expenditure. In fact, the research proposal is the conceptual structure within which research is conducted; it comprises of the plan for data collection and how data will be organised and analysed.

A good research proposal quickly and easily answers the following questions: what do you want to do? How much will it cost? How long will it take? What difference will it make to your school, society or nation? What has already been done in the topic of your interest? How do you plan to do the research? Will the results be evaluated? How will the results be communicated? The questions will be answered in different ways depending on the nature of the proposed plan. Most of the research proposals are between ten and twenty pages in length. A research proposal should not be longer than 2500 words, excluding list of references and appendices.

Importance of a geographical research proposal

Research proposal helps the researcher to focus on important issues about the study. It enables the researcher to focus on which research questions need to be answered, how the data will be collected, who will provide the data and where will the data be obtained. It gives the researcher a chance to evaluate the study by predicting the difficulties the research is likely to face and plan to solve them before.

The proposal acts as a guide to general strategies from the beginning of research to its completion. It sheds light on the expected costs of the research to enable budgeting for its completion. It also provides time schedule for the research. It guides the researcher to prepare materials and resources in a logical manner. The proposal enables the researcher to define the boundaries of the study and the concepts to be included. It should be noted that the better you organise your ideas at this stage, the more effective time and resources will be spent. Normally, a research proposal is written in future tense, since it is a plan to be implemented in future.

The format of a geographical research proposal

A research proposal must follow a format which is the general pattern of the organisation and arrangement of the proposal. This involves the following parts: *preliminary pages* which include the title of the study, the name of the researcher, abstract, table of contents and list of tables; *the main body* of the research proposal and *the appendices*. Basically, the main body of any research proposal is made up of five main components (see Table 2.1).

Title of the proposal: Is a summary of the main idea(s) of the proposal, normally short and precise, preferably not more than 20 words, giving a quick picture of what the proposal is about. The title should draw attention, create interest and desire to the reader to go through the entire document.

Abstract: Is a section that offers an overview of the entire research proposal ranging from the title to the methodology. The abstract has to be short, but capturing all important issues. It is the first section out of the 3 sections that consists of the background, statement of the research problem, research objectives, research questions or hypothesis, significance of the study, scope of the study and limitations. However, not all research proposals require an abstract.

Background to the research problem: In this part, the researcher provides background information on the topic of interest and arguments starting from global, regional to local levels. It is in this part where the researcher highlights on what is already known in the field, what is not known, and what the researcher wishes to reveal in the proposed study.

Statement of the research problem: This refers to the statement on what is the issue that needs the researcher's attention and its magnitude. The origin of the research problem may come as a result of reviewing literatures, own life experiences, discussions with colleagues or experts in the same field and others.

Research objectives: In this section the researcher should have the general and specific objectives. The general objective articulate what the researcher intends to achieve while specific objectives show how the main objective will be attained.

Research questions or hypotheses: In this section, the researcher chooses to use either research questions or hypotheses, depending on the nature of the problem and the field of study. For example, research questions are very common in social sciences while research hypotheses are widely used in natural sciences.

Significance of the study: In this section, the researcher explains why a particular research work is needed. Basically, it offers justification of conducting the proposed research and the impact it will develop. Moreover, it clarifies possible contributions to knowledge and highlights on how other researchers will benefit from it.

Scope of the study: This section narrows down specific issues which will be addressed in a particular research work. It is practically impossible to study everything, but focusing on one issue at a time. The scope of the study briefly indicates the study area, content and methodology. It is also known as the *delimitation* of the study.

Limitations of study: In this section, it is important to highlight research related challenges that the researcher encountered during the research process. Here, the researcher identifies the challenges and the means to overcome them. Generally, limitations affect the study design, results and conclusions. Thus, the researcher should explain how each limitation will be managed without affecting the quality of the study.

Review of the literature: This involves reviewing sources which are related to the subject matter stated in the title. It is a continuation and extension of the information provided in the background section but not repetition. It includes both theoretical and empirical reviews. By reviewing literatures, the research gap is identified; hence, the researcher avoids repeating what has already been done by other researchers. Therefore, the researcher becomes familiar with the area of study chosen.

Research methodology: In this section, the researcher precisely gives reasons for the choice of the study area, defines methods, tools, and techniques that will be used in selecting the sample, data collection, data organisation, data analysis, and results presentation. Additionally, the researcher indicates how the study will adhere to research ethics.

References: Refers to a list of all documents which have been used in preparing a research proposal and are cited in the text. It includes published and unpublished sources such as reports, journal articles, books, book chapters, newspapers, conference proceedings and others. It is always arranged alphabetically by considering the surnames and initials of the author(s) of the reviewed works, title of the reviewed works, publisher, and place of publication.

Appendices: Consists of important supportive attachments that should be cited in the appropriate area of the proposal such as the following;

(i) Data collection tools that will be used in the field.

(ii) Time frame: This is the time that will be taken from proposal writing to data analysis and reporting.

(iii) Funding and sources of funds: This is the proposed budget and the breakdown which specifies how funds will be used to complete the work. The research proposal format can be summarised as presented in Table 2.1 below.

Table 2.1: *Geographical research proposal format*

Preliminaries	Title page (which, among other things, consists of the research title), abstract, table of contents, list of figures and tables and acronyms/abbreviations used.
Chapter One	**Introduction** – background to the research problem, statement of the research problem, research hypotheses or questions, objectives of the study, significance of the study, scope of the study and limitation of the study.
Chapter Two	**Literature review** – discusses related works; it discusses what is already known about the research topic as a whole and outlines the key ideas and theories for the current research.
Chapter Three	**Methodology** – describes procedures used in research, study area, research design, sampling technique, data to be collected and how it will be obtained, organised, analysed and presented.
References	Here, resources such as books, documents and reports that have been used by the researcher in writing the research proposal and appear in the text are listed down in alphabetical order.
Appendices	Attachments which may contain some of the information related to the study such as research tools, figures, tables and photographs that should be cited appropriately in the proposal.

Geographical research report

Report writing is the last step in the research process. In this step, the researcher has to write a complete report of the scientific research undertaken. Research report is the process of communicating the results and the care that has been exercised throughout the study. In general, research report is a detailed account of the study conducted or systematic report of the findings of a research which describes the process and the data used in the study.

Components of a geographical research report

Normally, the research report should be written in a specific format as shown in Table 2.2.

Table 2.2: *Geographical research report format*

Preliminaries	Title page (which, among other things, consist of the research title), abstract, table of contents, list of figures and tables, certification, declaration and copyright, dedication, acknowledgement and the acronyms/abbreviations used in the study.
Chapter One	**Introduction** – background to the research problem, statement of the research problem, research hypotheses or questions, objectives of the study, significance of the study, scope of the study and limitation of the study.
Chapter Two	**Literature review** – discusses related works; it discusses what is already known about the research topic as a whole and outlines the key ideas and theories for the current research.

Chapter Three	**Methodology** – describes procedures used in research, data collected and how it was obtained, organised, analysed and presented. Here, the research gives details on 'what', 'how' and 'why' such research methods were used.
Chapter Four	**Results and discussion**– show the meaning of the presented research results, compares results from different sources included in the study (for example, from questions and observations) and relates the results to other researchers' works in the same topic. This is followed by a conclusion in each of the subsections.
Chapter Five	**Summary, conclusion and recommendations** – the conclusion normally summarises and interprets the major findings to describe what they mean. This part gives reasons as to why the findings are in that manner. In other words, it answers the question, "So what?" The recommendations explain what should be done and who should act to make the findings of the study meaningful to the society. Recommendations should be given in relation to research findings and not otherwise. In addition, this section also provides/identifies areas for further study according to study findings.
References	A collection of resources such as books, documents and reports that were used by the researcher in writing the report and appear in the text are listed down in alphabetical order.
Appendices	Attachments which may contain some of the information related to the study such as research tools, figures, tables and photographs that should be cited appropriately in the report.

Activity 2.4

Search for the materials from various sources then:

(a) Read about research format, summaries and organise your work based on the comments of research format.

(b) Summarise the tenses commonly used in writing a research proposal and research report.

Exercise 2.4

1. Compare the features of introduction and literature review as chapters in a research report.
2. Compare and contrast research proposal and research report.
3. Describe how a quality research proposal is a step forward toward solving a geographical research challenge.

Geographical variables and data

The word data is derived from a Latin word *datum* meaning 'something given'. Data can be numeric, text, graphic, art, image or symbol that researchers obtain from the subjects, respondents or participants of the study. It is a raw or unprocessed information about a certain phenomenon or event. The raw geographical data needs to be processed by subjecting it to some analysis in order to obtain useful information for decision making. The data that has been processed to get their meaning is referred to as *information*. Data can be obtained from various fields or topics namely: weather and climate, demography, transport and communication, as well as agricultural production. When one does any sort of inquiry or research, he or she will collect data of different kinds. In fact, data can be seen as the essential raw material of any kind of research. Data can be managed by using information technology in the form of bytes stored in electronic memory (database).

An individual piece of data in a data set is called a score or observation whereas a quantity to which any of a set of values such as scores or observations is assigned is called variable. For example, the *quantities* height, weight or age are variables, while the values assigned to them are data. In the case of qualitative data, colour of water can be green, reddish, milky, blue or colourless. The 'colour' is a variable while green, reddish, milky, blue or colourless are data.

Data can be collected from the respondents or subjects by using different methods such as survey, focus group discussion, document review and interview. Data may also be collected through any other method, depending on the needs of the research.

Nature of data

Data may be classified in four categories, namely: Discrete, continuous, individual and grouped data. Discrete data is a numerical type of data that can only be given in whole, concrete numbers with specific and fixed data values determined by counting. Examples of discrete data include number of people, computers, animals, houses and eggs.

Continuous data include complex numbers and varying data values that are measured over a specific interval or within a range. Values in these data set often carry fraction or decimal points. Examples of continuous data include height, weight, wind speed, temperature, altitude and distance. For example, temperature of 23.15° C in a range 0° C to 30° C or an altitude of 483.23 m in a range of 0 to 1000 m.

Individual data are data through which an exact value is given for each individual item in a sample. For example, the population of Tanzania, and number of students at Mjimwema secondary school which may be 200 students are types of individual data. Grouped data are data by which no exact figure is quoted, but several values fall within certain classes or groups. For example, grouping people according to their age ranging from 1-5, 6-10, 11-15, 16-20 to 85 and above.

Geographical data

Data are classified into three main categories on the basis of sorting or distribution, unit of measurement; and methods and sources. Basing on sorting or distribution, data is classified into ungrouped and grouped data. Ungrouped data (raw data) is concerned with raw facts that have been collected from the experiment or study and usually not sorted into categories. For example, 10, 15, 20, 25 and 30 vehicles. Furthermore, when expressing number of houses, people, employee and eggs we use whole numbers and we normally list them. Grouped data (array data) refers to a set of raw numerical facts that has been sorted or distributed into categories. For example, Tsh 10 001- 20 000, 20 001-30 000 and 30 001 - 40 000 or heights of people in centimetres 151-160, 161- 170, 171 - 180 and 181-190.

On the basis of unit of measurements, there are two types of data namely, categorical (qualitative) and numerical (quantitative). Categorical data are measures that normally describe the characteristics of the studied subject and can be in the form of text, graphics, art, image or symbol. Categorical data are further grouped into nominal and ordinal data. Nominal data are labelled or named data without a quantitative measure and often without logical sequence. For example, marital status (married, unmarried, widow/widower) occupation (hunter, employee, farmer), common elements of weather (temperature, rainfall and wind) and Yes/No responses. Likewise, ordinal data are labelled or named data without quantitative measure but with a logical sequence. For example, satisfaction, opinion or feelings.

Numerical data, are data expressed in numbers. Numerical data are further grouped into discrete and continuous data. Numerical data corresponds to interval and ratio data.

On the basis of methods and sources, data can either be primary or secondary. Primary data refers to the first-hand raw facts from an experiment or field. They are original and freshly gathered from the source. Primary data have several uses or advantages including originality and independence which increase the validity and enhance reliability of the data. They are used in both quantitative and qualitative studies. These are the only data which can explore from the hidden information through appropriate approaches. The data can also be transformed to secondary data after analysis. Primary data are however, likely to be influenced by expenses and time consumed in collecting them. They can be difficult to collect due to their complexity and high demand of commitment.

Secondary data refers to the second-hand data in published or unpublished form that was earlier collected by someone else and often passed through analysis and usage. Secondary data can be obtained from public or private offices and searched from websites and internet sources. Secondary data have a number of merits to researchers such as easy manageability time saving and low cost of accessing them. In addition, some are readily available in analysed form useful in complementing the existing data and demand less field work. However, the applicability of secondary data is limited in terms of lack of means to validate them, demand expertise and have less accuracy and reliability compared to primary data. Table 2.3 indicates the differences between primary and secondary data.

Table 2.3: *Distinction between primary and secondary data*

S/N	Description	Primary data	Secondary data
1.	Source	Original sources	Secondary sources
2.	Methods of collection	Observation, questionnaires, interview, focus group discussion, and measurements	Review of documents such as books, journals, magazines, research publications and website sources
3.	Analytical process	Not done	Done
4.	Originality of data	Original or first hand	Not original or second hand
5.	Use of data	For specific purposes of current study	For the purpose established by those who conducted such research
6.	Methods of data collection	Given	Not necessarily given
7.	Time consumed	More	Less
8.	Cost and accuracy	Accurate and expensive	May not be accurate but cheap

Variables

A variable is any characteristic, number or quantity of a person, object or phenomenon that can be measured or counted. A variable may also be called a data item that varies in magnitude. There are different ways in which geographical variables are described depending on the way they are studied. Variables are grouped basing on the scale of measurement, study designs and association. Basing on the scale of measurement, variables are described as numerical and categorical while in the study design, they are described as active and attribute variables and in causal relationships, they are dependent and independent variables (Figure 2.1).

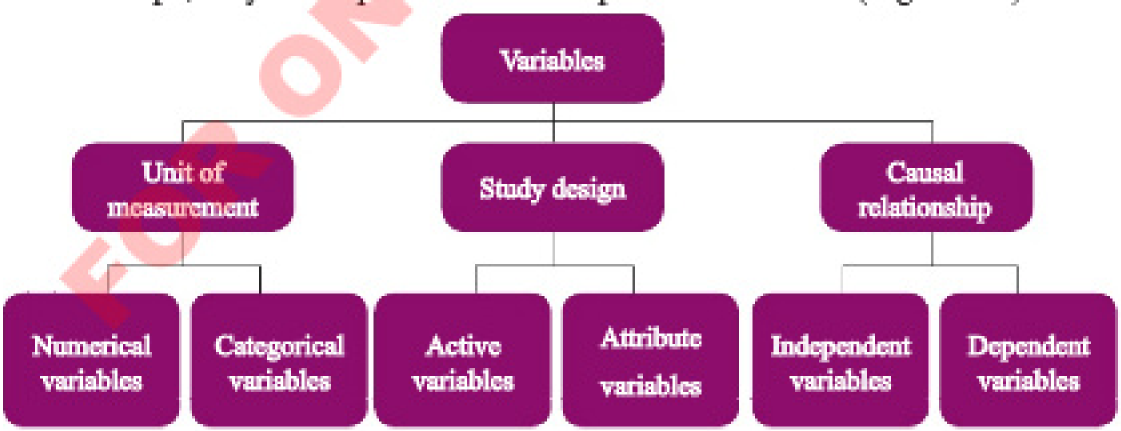


Figure 2.1: *Schematic representation of variables and respective classification criteria*

Numerical variables are variables that can be described as either continuous or discrete variables. The measurements for these variables are numbers. Continuous variable refers to quantitative variable which take any value in measurements normally within some ranges. They can be expressed in decimal places or fractions. Examples of continuous variables are height, time, age and temperature. Discrete variables are quantitative variables, which take isolated values in measurements. In other words, they are variables which cannot be expressed in form of a fraction or decimal places. Examples of discrete variables include the number of registered cars, houses and children which are all measured as whole numbers.

Categorical variables are qualitative in nature as they are represented by non-numeric values. They normally take a form of a text, image or symbol. Based on the nature of data, categorical variables are classified as ordinal or nominal variable. Ordinal variables deal with the value that can be logically ordered or ranked higher or lower than another without establishing a numeric difference. Examples of ordinal categorical variables include academic grades such as A, B and C; and clothing size such as small, medium, large and extra-large. Nominal variable deals with values and the classification of variables in which the logical sequencing of variables is not applicable.

Active and attribute variables differ with regard to manipulation. Active variables are those that can be manipulated, changed or controlled, while attribute variables are variables that cannot be manipulated, changed or controlled, and that reflect the characteristics of the study population. Examples include age, weight, height, income and level of education.

Independent and dependent variables

Independent variables are not usually affected or influenced by external factors for change. For example, someone's age cannot be influenced to change by either eating or better health services. *Dependent variables* are easily affected or influenced by external factors for change. For example, temperature, rainfall, body weight and academic performance are all likely to be affected or influenced by external factors. Generally, a *dependent* variable depends on the independent variable.

The measures that indicates the extent to which two or more variables are related is known as *correlation*. Correlation is concerned with quantifying the degree and direction to which two variables are related. Direction of relationship can be positive or negative while the degree of relationship can be perfect, very strong, strong, moderate, weak, very weak and zero (No relationship). Although it is maintained in correlation,that change in one variable may result to a change on another, such a change on the latter does not often imply causation. Sometimes there may be an unknown factor that affects both variables in the same way. A relevant example of a correlation is good market price of agricultural produce which may result into the increased production of crop since farmers enjoy good prices. Similarly, a relatively large Geography class may be correlated to poor performance of the students.

Relationship between variables

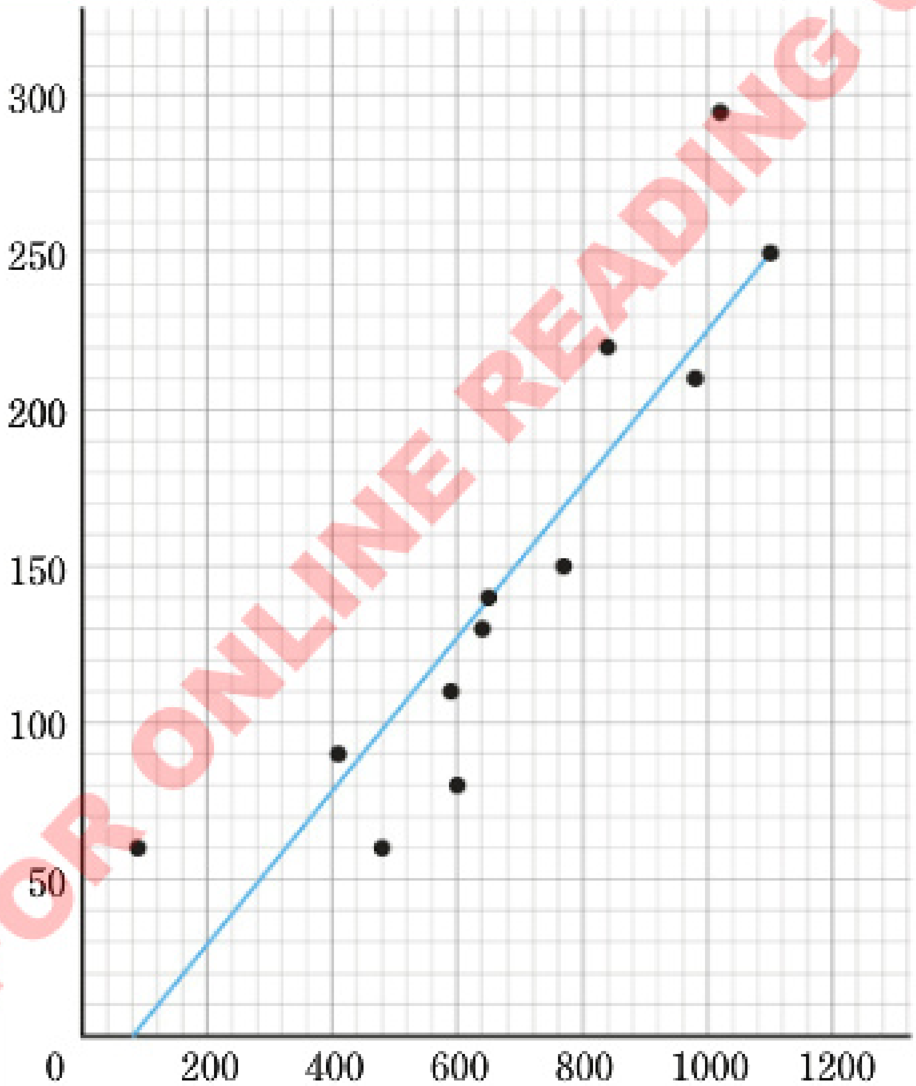
Variables are related in three different ways, namely positive, negative and no relationship as described hereunder.

(i) *Positive relationship*

This is the relationship which exists when an increase in the independent variable results to an increase in the dependent variable and a decrease in the independent variable results to a decrease in the dependent variable. For example, the hypothetical data in Table 2.4 demonstrates a positive relationship between annual rainfall and the runoff generated (Figure 2.2).

Table 2.4: *Annual rainfall and runoff generated in the hypothetical catchment*

Rainfall (mm)	90	410	480	600	590	640	650	770	840	980	1020	1100
Runoff (m^3)	60	90	60	80	110	130	140	150	220	210	295	250



Scale: Horizontal scale: 1 cm to 200 mm; Vertical scale: 1 cm to 50 m^3

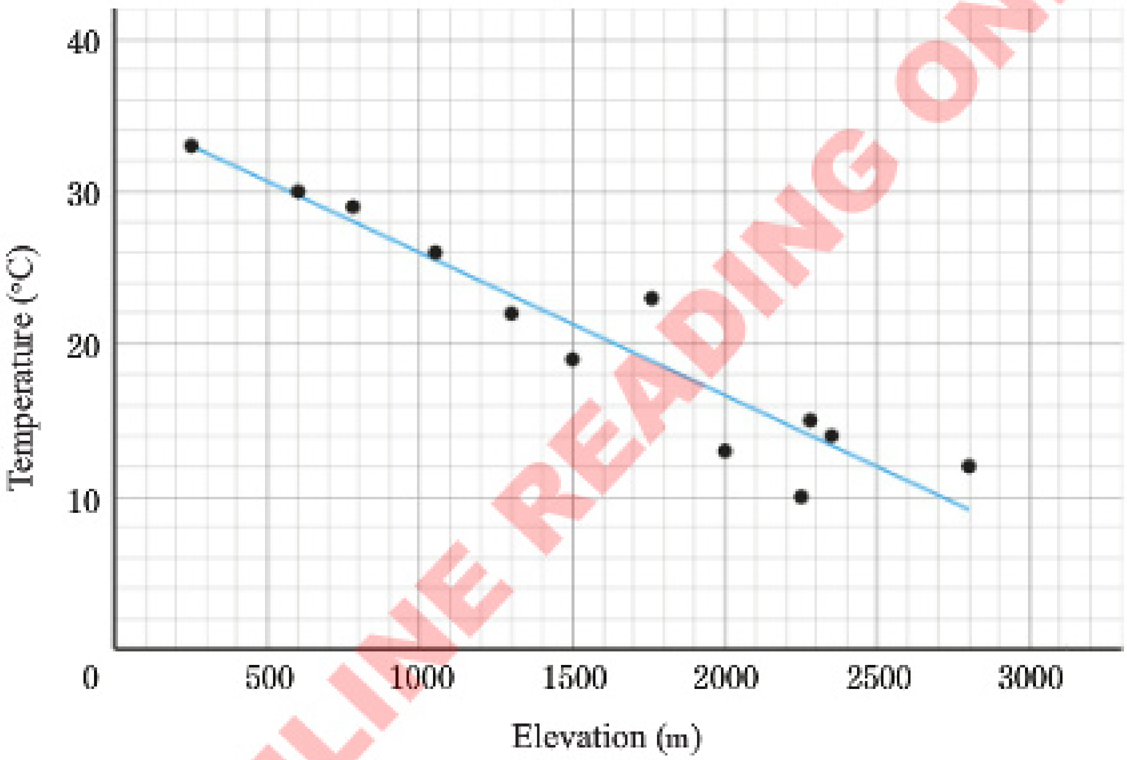
Figure 2.2: *Positive relationship*

(ii) *Negative relationship*

This is a relationship where the variables are negatively or inversely related, that is, when independent variables increase, the dependent variables decrease. For example, atmospheric temperature decreases with increase in elevation above sea level as shown in Table 2.5 and Figure.2.3.

Table 2.5: *Temperature recorded on a hypothetical land with varying elevation*

Elevation (m)	250	600	780	1050	1300	1500	1760	2000	2250	2280	2350	2800
Temperature (°C)	33	30	29	26	22	19	23	13	10	15	14	12



Scale: Horizontal scale: 1cm to 500 m; Vertical scale: 1cm to 5 °C

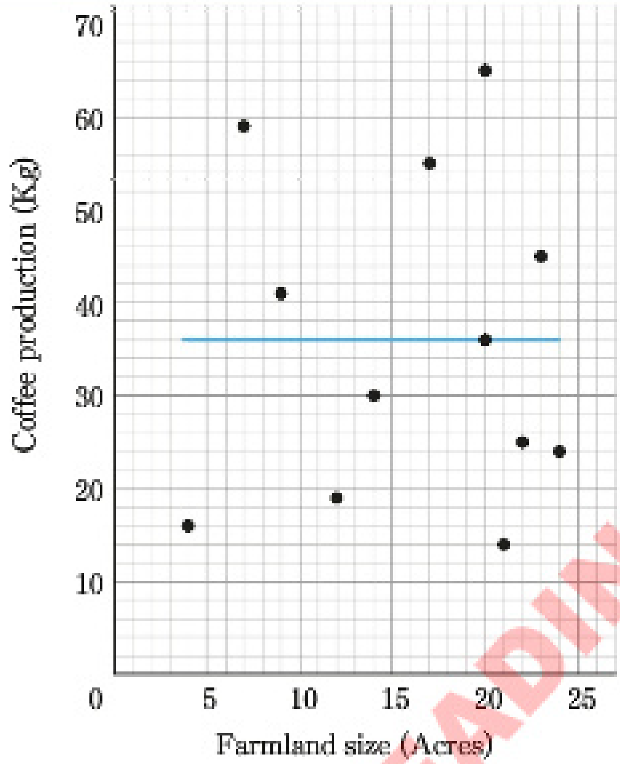
Figure 2.3: *Negative relationship*

(iii) *No relationship*

This occurs when there is no direct relationship between variables. As such, change in one variable does not cause any change to the other. For example, the quantity of coffee production (Kg) may not necessarily be influenced by the size of the farm. The farm size can be large but production may be high or low depending on other factors such as soil fertility, moisture and other factors as shown in Table 2.6 and Figure 2.4.

Table 2.6: *Coffee production on farmlands of different sizes.*

Farmland size (Acres)	12	9	14	7	17	4	20	20	21	22	24	23
Coffee production (Kg)	19	41	30	59	55	16	36	65	14	25	24	45



Scale: Horizontal Scale: 1cm to 5 acres; Vertical Scale: 1cm to 10 Kg

Figure 2.4: *No relationship*

Activity 2.5

1. (a) Survey your school premises including offices and library and identify five types of data commonly recorded at the school.
   (b) Describe the uses of the identified types of data within the school.
2. Assume you are planning to conduct a study on climate change adaptation strategies in your chosen sector. Then:
   (a) Identify the possible data that you will collect; and
   (b) Classify the identified data from (a).

Exercise 2.5

1. Explain the uses of geographical data in our daily life.
2. Describe the criteria used to classify geographical data.
3. "Both primary and secondary sources of geographical data are of paramount importance". Elaborate on this statement.
4. State differences between the following types of data:
   (a) Categorical and numerical
   (b) Single and grouped
   (c) Discrete and continuous

Geographical research process

In order to study and solve a geographical research problem, a research has to appropriately follow several stages in a systematic manner. Failure in any stage is likely to affect the whole research process. In order to work systematically, the research process or stages goes through a series of actions which are as follows:

Background to the study

Background information can differ depending on the field, topic, or issue being studied, though generally, it provides an overview of the area of interest to the researcher. Despite this, there are some common features that a researcher ought to observe. The researcher is supposed to maintain focus on the area of interest, the existing phenomenon, or a puzzle that requires scientific answers from a research. Depending on the nature of the phenomenon, the researcher can be compelled to show its prevalence from the global level, region (for example, in Africa, sub-Saharan Africa, or East Africa), through Tanzania, to the location where the proposed study will be conducted. For instance, if the researcher wants to investigate the coping strategies for domestic water accessibility among the community members in a certain area, then should first describe the current state of water scarcity globally, regionally, then in Tanzania as well as in the specific area in which the study will be conducted. The researcher can describe the extent of the effect of water in terms of intensity, effect, percentage, or victim count from the global to the local level. The researcher should also explain the causes of water scarcity and associated factors that intensify the phenomenon to be investigated.

The researcher has to provide an explanation on any laws, regulations, plans, and other strategies, whether they come from governmental or institutional sources. The researcher should present the literature that already exists and has documented the topic of interest. At this stage, the investigator ought to establish the existing knowledge and the unknown. The unknown will form a research gap that will be specified in the statement of the research problem.

Activity 2.6

Develop a research title of your interest based on an identified geographical challenge. The title should contain the area in which the research will be conducted, where the problem exists. Then, write the background of your research based on the developed title and indicate the area in which the study will be carried out.

Formulating the geographical research problem

Formulating of a research problem is an important step that will uncover what problem is worthy studying by explaining clearly what has been documented, what has not been documented and what needs to be documented. The main function of a research problem is to determine what needs to be researched. Basically, the main sources of a research problem include conversation with people from whom you can gain insights and find out the existing imbalances, research gaps and issues to be researched.

Moreover, a research problem can be identified by exploring the interventions and programmes that have been in place. Examples may include exploring from the projects and activities aiming at empowering the community adaptation to the impact of climate change, exploring from projects on promoting students' performance in secondary schools, poverty eradication programmes, restoration of soil fertility programmes and intervention on increasing the dissemination of weather and climate change information. Therefore, through critical studying in such areas, one may decide to evaluate the effectiveness of one of those interventions.

Another way of establishing a research problem is based on experiences evaluating some existing phenomena and establishing some areas worth to be researched. For example, one may decide to focus on the problem of water scarcity in arid and semi-arid areas and decide to study the existing adaptation mechanism for water scarcity. As a starting point in thinking how to develop a research problem, the following samples of a geographical research problem can be useful guides to you:

Geographical challenge 1: In Tanzania, the effects of plastic waste on land, water bodies and living organisms is evident. In comparison to rural areas, the risk is greater in urban areas due to the reasonably higher generation rate of plastic waste. Plastic waste from sources based on land is one of the growing environmental problems in water bodies in some regions of Tanzania, particularly Dar es Salaam, Mtwara, Mwanza, Mara, Kagera, Rukwa, Ruvuma, and Mbeya, as well as Zanzibar Islands. The adjacent water bodies, such as lakes, rivers, and seas, are extremely polluted by plastic waste from those areas. The rise in plastic waste is mostly due to several factors, such as a mismatch between waste generation and collection capacity, business expansion, and weak enforcement of environmental laws.

Previous reports demonstrate the diverse approaches to plastic waste management that have been implemented, such as environmental policies, diverse programs and initiatives, public education, and a focus on reusing, reducing, and recycling of plastic wastes. Despite these initiatives, plastic waste has remained persistent. However, little research has been done on the role that local institutional coordination plays in reducing plastic waste. Therefore, this study aims to investigate the role of local institutional coordination in managing plastic waste in the selected sites in Dar es Salaam and Zanzibar Islands.

Geographical challenge 2: Various measures have been taken by the government of Tanzania in collaboration with various internal and external stakeholders in eradicating malaria in the country. Such measures include improvement of health facilities; diagnostic measures and medications; awareness raising on environmental cleanliness; removal of stagnant water in our neighbourhoods; and provision of protective gears such as mosquito nets. Despite all these measures, malaria incidences have kept on increasing in the country.

Although various studies have been conducted on the challenges of malaria and the effectiveness of malaria control measures, information is lacking on the sociocultural factors influencing control of malaria in the country. Lack of studies of this nature is likely to limit the government efforts towards creating a malaria free society, thus government's burden on treating the victims will keep on increasing. Therefore, this study is geared towards that end.

Geographical challenge 3: It is an acceptable fact that the impact of climate change is affecting all people equally but differently in different parts of the world with slight variations across gender differences. Most of the studies have documented how women have been affected by the impact of climate change and associated adaptation measures. However, there are limited studies on the extent of impact of the climate change to the elderly population and the adaptation measures to this social age group. Failure to document this area means that the vulnerability to the impact of climate change and social disturbance will keep on increasing and many of the elderly in society will be negatively affected. Therefore, this study is an attempt to that end.

Considerations in selecting a geographical research problem

For manageability and sustainability, the researcher should consider the following when selecting a research area or a research problem. Firstly, interest in the area makes the researcher to be motivated throughout the research process. Secondly, it is important to consider the magnitude of the selected topic. This will enable the researcher to balance time and resources for completing the study on time. Therefore, the researcher is required to narrow down the topic to make it manageable, specific and clear. Thirdly, the researcher should make sure that the indicators and concepts studied are measurable and verifiable. Fourthly, the researcher should have adequate and appropriate research knowledge and skills to address the problem to be studied. Fifthly, the researcher should focus on a relevant research problem that is likely to fill the existing knowledge gap, add new knowledge and improve practices in the researched area. This will be an additional aspect to sustain the interest of the study. Sixthly, consideration of ethical issues in relation to the area the researcher plans to study is of great importance. This item requires the researcher's professionalism and flexibility. For example, dealing with sensitive researches in areas like victims of floods, earthquakes and any environmental hazards/disasters and other diseases require flexibility and professionalism in order to approach the problem wisely and successfully.

Criteria for a good geographical research problem

There are a number of criteria that need to be considered in writing a research problem. A good research problem should adhere to the following qualities: Firstly, it should be novel, that is to say, the problem should come up with a new process, product or principle that can help in improving practices. Secondly, it should be interesting in the sense that it draws attention and interest to other people. Thirdly, it should be innovative meaning that it improves the current or existing state of affairs and possibly technology. Fourthly, it should be cost effective in such a way that it produces good value for money, time and resources. It should be addressing a problem in the community.

Challenges of writing a geographical research problem

There are many challenges facing researchers in their attempt to write quality research problems. Some of these challenges include difficulties in deciding on the topic for research, lack of good knowledge of the methodology to be used, inability of finding current, specialized and related references such as books, lack of interest in research, lack of understanding of the subject matter, structure of time limit and lack of good research guidance. Others are misconception of the research problem; for example, one may think that if some people in the community do not have money, the research problem will be inadequate fund. This will make a study something different from the problem because lack of money is an outcome of something else such as unemployment.

Activity 2.7

Based on the research title developed in Activity 2.6, formulate the research problem. The problem should indicate the area in which the research will be carried out. Then, state the significance of the proposal you have started developing from Activity 2.6

Geographical research objectives

Research objectives are normally developed after stating the research problem. They emerge from the problem as they intend to make the research focused and answer the research questions or cover the gap developed in the statement of the problem. Research objectives should be closely related to the statement of the research problem and summarise what is intended to be achieved by the study. Good research objectives are useful in defining the focus of your study as they clearly identify the variables to be measured; describe actions to be taken in establishing the limit of the study; guide the researcher by avoiding collecting unwanted data for answering the research questions. Normally, research objectives are stated in such a way that they start with *action verbs* that can easily be measured, for example, 'to compare'..., 'to assess...', 'to determine...', 'to verify...' 'to identify...', 'to examine...', 'to measure...', 'to explore...'. Strictly avoid the use of vague non-active verbs of state in stating objectives such as to appreciate, to understand, to believe, to study, and to think because it is difficult to evaluate whether they have been achieved. Such verbs represent an abstract situation, such that even in the field, it will be difficult to get data from respondents in case the research deals with people.

Activity 2.8

Based on the formulated research title in Activity 2.6, formulate three general objectives and from each of the general objectives formulate three specific objectives. The area in which the research will be carried out should be indicated in the specific objectives.

Exercise 2.6

1. Clearly describe the link between the statement of the research problem and research objectives.
2. Why are action verbs taken into consideration when stating research objectives?
3. A well written research proposal situate the intended research against other existing related research. Explain.

Review of the literature

Once the problem is formulated, a brief critical review and summary of it should be written down. At this point, the researcher should undertake extensive literature survey connected with the problem. Literature review is concerned with reading of various previous related publications in order to enable a researcher to be aware of how other researchers have addressed the same or related research problem. Literature review helps to avoid unnecessary repetition of studies which have already been conducted. It helps the researcher to redefine his or her research problem, to select an appropriate sample, appropriate tools and the research design.

Generally, literature review is important in clarifying and focusing the research problem and in sharpening the research methods that you will use in your study by looking at how others have used them. Literature review also enables the researcher to broaden knowledge in the selected area to situate the study against other related research to avoid duplication. Furthermore, it helps to identify the research gap and challenges likely to face the research process.

A good literature review can be distinguished by several criteria. First of all, a literature review should be capable of outlining the important study trends showing the current situation, information and documentation that have been done in the area in which the researcher is proposing to carry out a study. The second criterion is that, literature review needs to assess the strengths and weaknesses of the existing researches in different orientations including whether methodological approaches used in the existing studies were relevant. Furthermore, literature review should assess the strengths and weaknesses of the arguments, conclusions and assumptions made by the existing studies.

The third criterion is that literature review should identify knowledge gaps from the existing studies. In other words, literature review should not be written plainly, that is, agreeing with most of the past literature in their entire dimension. In this case, there would be no need of conducting another study because it would be a duplication of the research unnecessarily and wastage of resources and time. The fourth criterion is that a good literature review should be based on most recent existing literature from which one can establish a research gap and position their work among other related studies. To sum up literature review acts as a lock and key that specifies clearly the research gap. In this part, you will be in a better position to know what is needed in the research you are planning, where to conduct it, and how your findings fill in the gap you have established.

In writing the literature review the checklist can be guided by the following questions:

- Based on the related literature, what is currently known about the chosen geographical issue of interest, from a global (general) perspective to a specific one (Tanzania)?
- Which previous work has been done so far?
- Which concepts have already been built?
- What is lacking from each of the empirical literature review's subsections?
- How do the sub-gaps align with the project's question, research objective, and problem statement?

Activity 2.9

Based on the formulated research title in activity 2.6 write the literature review.

Exercise 2.7

1. Why do we do literature review?
2. How does the literature review link stages of research?
3. A well-written research proposal situate the intended research against other existing related research. Explain.

Hypothesis formulation, testing and research questions

After extensive literature review, the researcher should state clearly the working hypothesis. Hypothesis is a tentative assumption formulated to draw out and test its logical or empirical consequences. It is a tentative statement about the relationship between two or more variables. A hypothesis provides the focal point for research, guides the researcher by delimiting the areas of research and keeps them on the right track. Hypothesis also indicates type of data required, methods of data analysis and draws conclusion.

Basically, there are two types of hypotheses: null hypothesis and alternative hypothesis. Null hypothesis is stated in a negative way or by using a negative statement. Example can include *there is no relationship between population growth and development; there is no relationship between the rate of survival in hazards and awareness; smoking is not a cause of cancer; existence of informal institutions is not associated with minimal conflicts in project areas.* Alternative hypothesis is stated to indicate the actual expectation or relationship. It is usually a positive statement about certain variables. Example may include *there is a relationship between truancy in schools and poor performance in academics; there is a relationship between the rate of survival in hazards and awareness; existence of informal institutions in water projects is associated with minimal conflicts in the project areas.*

Generally, there are many sources that can be helpful to a researcher to formulate a hypothesis. The main sources of hypothesis formulation include personal experiences, imagination and thinking, observation of phenomena, scientific theories, reviewing previous studies and cultural disposition.

A well stated hypothesis can be identified by observing the following criteria: it should be stated in the simplest terms for easy understanding; it should avoid conflicting with any law of nature which is known to be true; and should allow the application of desirable reasoning. Other qualities of hypothesis include being limited in scope and specificity; it should be capable of being tested within a specific time; and it should allow the application of *deductive reasoning*. Deductive reasoning is a reasoning that starts with a general problem or hypothesis and eventually narrowed down to a precise logical conclusion.

Geographical research questions

Research questions are the specific issues that the study wants to investigate from data collection and that data will answer them. In writing research questions, one can replace the first words used in the hypothesis "*There is*" with the words "*is there*" and also replacing the period with question mark. *For examples, Is there any relationship between population growth and development?*

Types of research questions

There are three types of research questions which are as explained below.

Descriptive research question; this seeks to identify and describe some phenomenon. *For example: Will the rate of survival increase after awareness raising?*

Differences research question; this asks if there are differences between groups on some phenomenon. For example, *do students who engage in remedial classes perform better than students who engage in sports activities?*

Relationship research question; this asks if two or more phenomena are related in some systematic manner. For instance, *is the existence of informal institutions in water projects associated with minimal conflicts in the areas?*

Activity 2.10

Based on the research objectives developed in Activity 2.8, develop the research questions.

Exercise 2.8

1. How do hypothesis and research questions play part in narrowing the study?
2. Explain how you would differentiate a collection of hypothesis.
3. How does the research hypothesis differ from a research question?

Research design

Research design is concerned with a systematic and well-planned means for conducting a research. It is a systematic way of finding out new knowledge. A research design is a conceptual structure for conducting the research. Preparation of the research design will smoothen the processes of sampling, methods and tools for data collection, analysis, interpretation and reporting. It will also reduce unnecessary expenditure by having predefined activities and resources. Usually, research designs vary with varying nature of studies. The commonly used research design are, 'snap-shot' or baseline sometimes called case-study, cross-sectional, longitudinal and experimental research designs.

Snap-shot or baseline research design is concerned with in-depth studies aimed at searching for the current and past behaviours and experiences for a single person, family, group, or organization. Usually, the findings from this kind of design cannot be generalized.

Cross-sectional research design is a survey design in which data are collected at one point in time from a predetermined population. Data from this design is normally used to describe the characteristics of the studied sample with regard to the population when data were collected.

Longitudinal research design is a form of survey in which data from the same area is collected at regular intervals for the sake of investigating the changes of a studied population over time. It can be after several months or years. For example, regular research on the melting of ice caps at top of mountains like Kilimanjaro Mountain has contributed to raising public awareness of long-term climate.

Experimental research design can be used to establish cause - effect relationships between the independent and dependent variables by means of manipulating the variables studied by controlling them or randomisation. Alternatively, the studies conducted by using this design can compare groups that are closely related or introduce an intervening variable from which a researcher can examine changes among the groups. For example, studying two groups in which one of the two was intervened with an activity or project and the other not subjected to an activity.

Activity 2.11

Choose the relevant research designs to guide your proposed research that you started in Activity 2.6.

Exercise 2.9

1. Researchers are selective on research designs. Explain.
2. In what ways does a research design act as a determinant of research?
3. The required data in any research are selective on research design. Explain.

Target population, sample and sampling techniques

Target population, sample and sampling techniques are among the many terms used in geographical research. Below are important definitions of the terminologies commonly used in studies dealing with population.

Target population: This is the entire population that the results of the survey should be representing. The target population can be the entire country, region, district, intervened villages, crop-land, rivers or cattle. Normally, the sample is selected from the target population. In case of a small population, it is advised to study the entire population.

Activity 2.12

Identify the targeted population based on the research proposal prepared in Activity 2.6.

Sampling frame: is a list of units in the population, for example a register of workers at an X secondary school in Mwanza, students' enrolment from the attendance register, and a list of pastoralists in a ward or village Y. Sampling frame tells who will be included or excluded in the expected research and why. The sampling frame contains the actual number of individuals to be sampled. The sampling frame should be checked from time to time to avoid mistakenly involving such individuals in total number of individuals to be sampled. The list should also be updated as required. For instance, it is better to get the sampling frame from the studied village rather than depending on the census which may sometimes be out of date.

Activity 2.13

Based on the targeted population identified in Activity 2.12, state your sampling frame.

Elements: These include individual persons, objects, or units about which information is collected. Thus, totality of elements forms population.

Sample: The sample is also known as the *subset* of the target population because it is selected from the population. It is also referred to as the composition of the set of elements from the population. Sample must be selected according to principles of sampling techniques to obtain a sample representative of the entire population.

Sample Size: is a proportional set of elements selected from the target population. Often, in probability studies, it is recommended that the sample should be optimal enough for data collection. Too small sample size is likely to increase errors in the data to be collected while too large sample size will have implications on time and cost. However, it is generally recommended that sample size should be proportional to the size of the population in case of finite universe. That is to say, the larger the population, the larger the sample and the smaller the population the smaller the sample. In probability studies, sample size can be estimated by using scientific methods as shown in the formula (a) and (b) below.

(a) For the finite population

$$n = \frac{N}{1 + N(e)^2}$$

Where;

n = sample size, N = population size (for example total households), and

e = the level of precision (desired margin of error)

For most common levels of confidence, 'e' equals as follows: 90%:e = 0.1, 95%:e = 0.05, 99%:e = 0.01, 99.9%:e = 0.001

Examples:

Assuming the basic population amounts to 1000 persons and the desired margin of error is 0.05, then the minimum sample size would be:

$$n = \frac{1\,000}{1 + \left(1\,000 \times (0.05)^2\right)} = \frac{1\,000}{1 + 2.5} = 286$$

This means data from 286 randomly selected respondents would be needed for the survey.

(b) For infinite population

$$n = \frac{Z^2 \times p\ (1-p)}{e^2}$$

Where;

Z= the area under the normal curve corresponding to the defined level of confidence

p= the true share of the population that displays a certain characteristic (for example, female population)

e = the desired margin of error

For most common levels of confidence, equals as follows:
90%: Z = 1.645; 95%: Z = 1.960;
99%: Z = 2.575; 99.9%: Z = 3.290

For example, for a population in which 48% are female and the desired margin of error is 0.05, the minimum sample size would be:

$$n = \frac{1.96^2 \times 0.48 \times (1 - 0.48)}{0.05^2} = 384$$

Moreover, the formula for getting sample size for infinite population can also be used when intending to estimate the minimum acceptable sample in the finite population.

Activity 2.14

Determine the sample size based on the sampling frame started in activity 2.13

Exercise 2.10

1. Explain why researchers strive to maximize the size of the sample for collecting data.
2. Compare and contrast population and sample size.
3. Compare and contrast target population and sampling frame.

Sampling techniques

Sampling is a process of selecting a representative of a population from which the data will be drawn on behalf of the entire population. The targeted population is being reduced to the sample at this point, so the researcher needs to pay a great attention in making choice of representatives. Dealing with a sample is rewarding in many ways. The appropriately selected sample will save resources and time, ensure accuracy and produce manageable data.

A well-designed sample can represent the intended population. The major categories of sampling techniques are probability and non-probability sampling.

Probability sampling

It is a method of selecting sample whereby every individual in the population has on equal chance of being selected. Probability techniques include simple random sampling, systematic sampling, stratified sampling, cluster sampling, and multi-stage sampling.

Simple random sampling technique

It is the basic sampling technique whereby each member from the population has an equal chance of being chosen. Each individual is chosen entirely by chance and each member of the population has an equal chance of being included in the sample. For example, a class of twelve students may write their codes on a piece of paper, and then the papers are rolled and mixed. Then one of the students can pick randomly only four codes for students to be included in the sample (Figure 2.5).

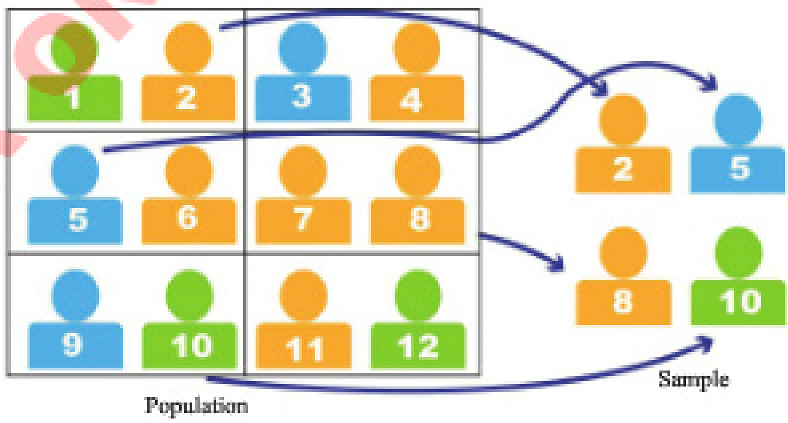


Figure 2.5: *Simple random sampling technique.*

One of the important things about simple random sampling is its ease of use in choosing the sample. It is also considered as a fair way of selecting a sample from a given population since every member within the target population is given an equal opportunity of being chosen. Another interesting feature of simple random sampling is the representation of the population. It is unbiased and the representative sample enables drawing conclusions from the results of the study. Therefore, simple random sampling is reasonable in generalising the results of the sample to population from which it is drawn.

Despite all the advantages explained above, simple random sampling technique has the following limitations. Firstly, it needs a complete list of all the members of the population. Thus is only convenient when working with small population that has already been identified and listed. Secondly, simple random sampling can provide accurate results, but it will not give you detailed information about specific groups of people. Furthermore, the technique is not practical to a large sampling frame. Lastly, the technique can distort representation of the minority groups of interests, and it is time consuming with high labour requirements in case of large population.

Systematic sampling technique

Systematic sampling is a random sampling technique in which members from a larger population are selected based on regular interval and systematic order. Thus, a sampling interval is required.

Sampling interval K = $\frac{N}{n}$

Where;

N = The number of elements in the population.

n = The number of elements for the sample.

In systematic random sampling, the researcher first randomly picks the first item or subject from the population. Then, the researcher will select each subject from the list. For example, in a class, the researcher may decide to pick every third student in a row to get a total of four students as a sample. For instance, if N = 12 and n = 4, therefore

$K = \frac{12}{4} = 3$. In the first 3 elements, number 2 is picked randomly. Then for the next three numbers, one number is picked at every third member (Figure 2.6).

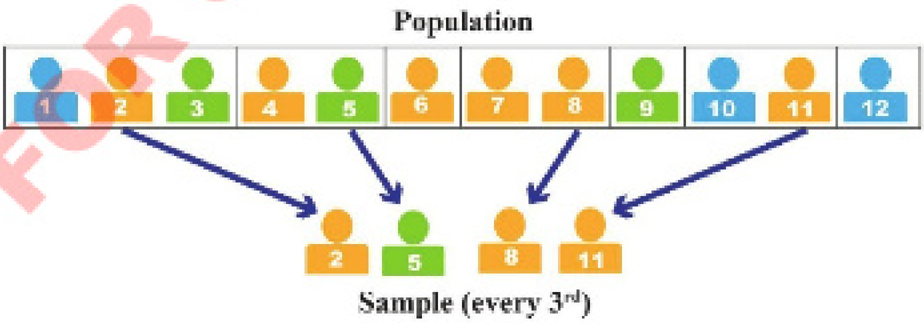


Figure 2.6: *Systematic sampling technique*

Systematic sampling has several merits. One of the primary advantage is its suitability in large target population. The assurance that the population will be evenly sampled to ensure even coverage of an area is another advantage. The technique is simple to use since it saves time and cost.

Systematic sampling technique is also accompanied with some bias and errors in case of hidden periodicity or order within the population that may distort the representation of a population. This happens, particularly when periodicity matches with the sampling interval in the list of the frame. Furthermore, systematic sampling is difficult to adjust sample to suit the circumstances and it is not practical for fragmented strata.

Stratified sampling technique

This is a probability sampling technique whereby the researcher divides the entire population into different sub-groups or strata, then randomly selects the final proportionally from different strata. The population is based on strata. Stratification is the process of dividing members of the population into homogeneous subgroups before sampling. Every element in the population must be assigned to only one stratum; then simple random sampling or systematic sampling is applied within each stratum. The obtained samples from the strata is added to form the entire sample. Examples of strata or sub-groups from a population include men and women, rich and poor, employed and unemployed.

The measurements within strata have lower standard stratification which gives a smaller error in estimation. In many applications, measurements become more manageable when the population is grouped into strata. It is often desirable to have estimates of population parameters for groups within the population. Several conditions must be met for it to be used properly. Researchers must identify every member of the population being studied and classify them into one, and only one sub-population.

However, the sorting process becomes more difficult and inaccurate for each member of the population stratum. It is also inconvenient as it may require more administrative clearance in various strata and the computational complexity is another constraint. Figure 2.7 shows three strata: A, B, and C, one stratum with 6 members and the other two with 3 members each. Proportionally, the 2 strata with 3 members each will be presented by 1 member and the one with six will be represented randomly by 2 members.

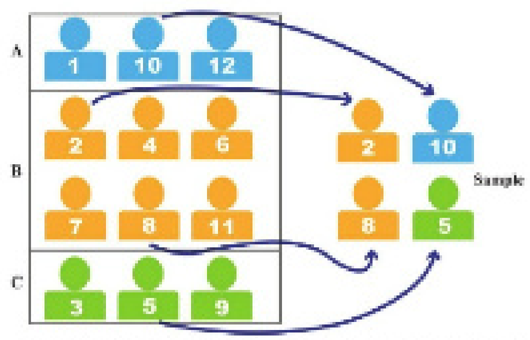


Figure 2.7: *Stratified sampling technique*

Cluster sampling technique

It is one of the probability sampling technique which is used when the total area of interest is large. The sample is obtained by dividing the area into a number of small non- overlapping areas and then samples are selected randomly from these smaller areas called clusters (Figure 2.8). This is applied when the entire population is unclear or unknown and the sample clusters are geographically convenient. When the clusters are natural in a population, cluster sampling is less expensive and quicker. Cluster sample permits each accumulation of large samples. The loss of precision per individual case is compensated by the possibility of studying larger samples without extra cost. The cluster sampling procedure enables obtaining information from one or more areas.

In cluster sampling, each cluster may be composed of units that are not similar. This pattern has a likelihood of producing large sampling error and reducing the representatives of the sample. In cluster sampling, when unequal size of some of the subsets is selected, an element of sample bias is likely to rise. This type of sampling does not allow generalisation of its findings to another area. In Figure 2.8, there are six clusters: A, B, C, D, E, and F where two clusters C and F have been randomly picked.

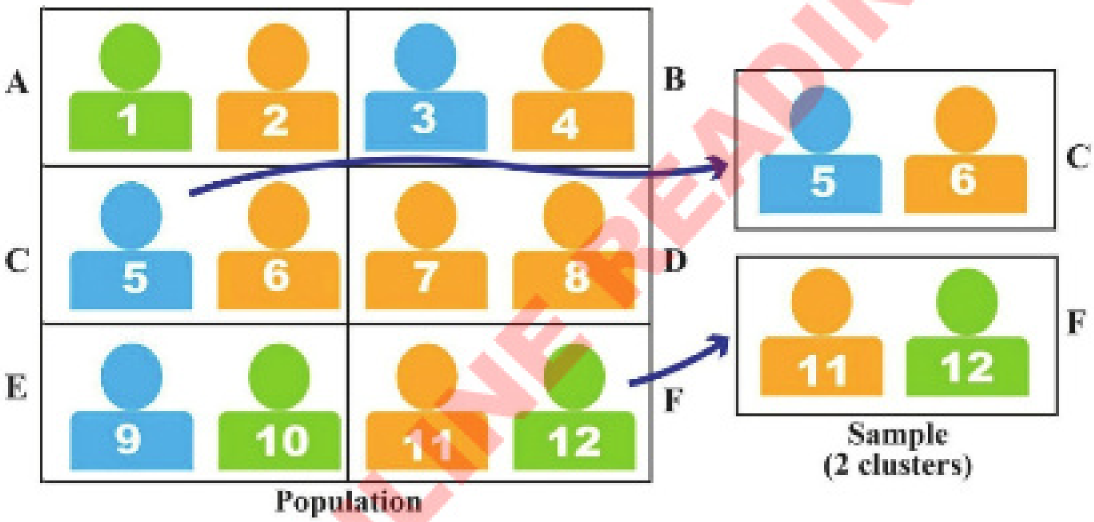


Figure 2.8: *Cluster sampling technique*

Multi-stage sampling technique

Multi-stage sampling is concerned with taking samples of preceding random samples. This sampling technique is more complex than cluster sampling which contains two or more stages in a sample selection. In simple terms, in multi-stage sampling, large clusters of population are divided into smaller clusters in several stages in order to make primary data collection more manageable (Figure 2.9). This technique probably solves more of the problems inherent in random sampling. It is more useful in incidents where there are completely no sampling frames. Moreover, by avoiding the use of all sample units in all selected clusters, multi-stage sampling avoids the large and perhaps unnecessary costs associated with traditional cluster sampling.

By considering a study with already pre-determined households in Tanzania, through simple random sampling, one can choose a number of regions let us say five, and out of five they may choose through randomisation four districts in each region. Furthermore, from the districts chosen one may choose four wards and lastly two villages from each ward. From these villages, it is where five households will be picked randomly for administering a questionnaire. Hence, the total sample size in the multi-stage sampling technique is a product of region, district, ward, villages chosen, that is $5 \times 4 \times 4 \times 2 = 800$ households. This technique is effective in primary data collection from a geographically dispersed population when face-to-face contact is required. It is also time and cost effective and has high level of flexibility. However, it has limitations such as high level of subjectivity, lack of representation of the population and complex planning and administrative issues are required to accomplish.

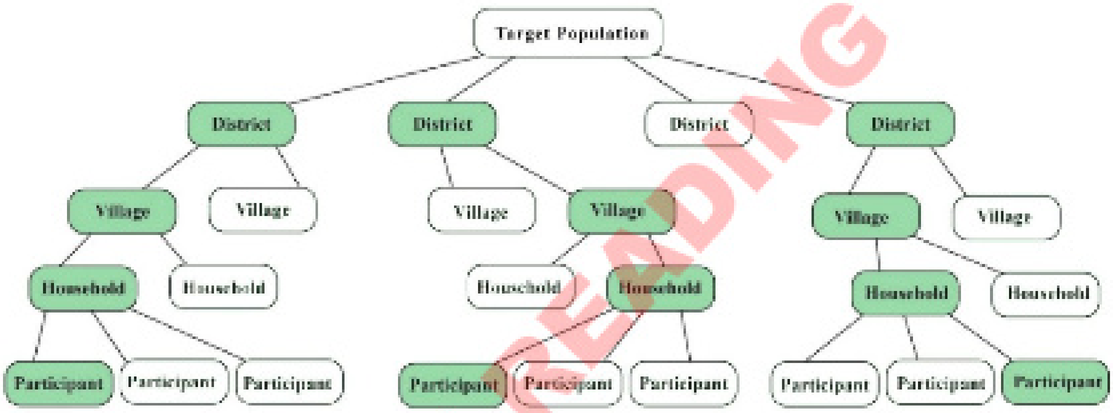


Figure 2.9: *Multi-stage sampling technique*

Note: The shaded boxes indicate the randomly selected cluster or a participant who has been selected.

Non probability sampling

This is a type of sampling in which members of the population have no equal chances of being included in the sample. Members to be included in a sample are chosen from the population in some non-random manners. Non probability sampling consists of quota sampling, convenience sampling, purposive sampling, snowball sampling and voluntary (self-selected) sampling.

Quota sampling technique

Under quota sampling techniques the interviewers are simply given quotas to be filled from different strata with some restrictions on how they are to be filled. In other words, the actual selection of the item for the sample is left to the interviewer's discretion. For example, the researcher may be asked to draw a sample of 35 females and 45 males aged between 45 and 60 from a certain population. The technique lacks the representativeness and it is biased.

Convenience sampling technique

This is a type of non-probability sampling technique which is applied when the members of the population are convenient to the sample. Convenience sampling is also known as grab or opportunity sampling or accidental. In this technique, most of the elements in the population that happens to be present at the time of conducting research are selected for the study. The researcher opts for it when he/she is interested in obtaining information cheaply. Like many other non-probability sampling techniques, it faces the limitation of lacking representativeness and it is subjected to biasness.

Purposive sampling technique

This is a type of non-probability sampling where a researcher selects only those cases, thought to be typical characteristics of the population. Purposive sampling is also known as *judgemental sampling*. The researcher selects the samples based purely on self-knowledge and credibility. In other words, researchers choose only those people whom they deem fit to participate in the study. In this technique, the researcher has to some extent, an assumption that the chosen respondents are knowledgeable on the topic being studied.

Purposive sampling technique has the following limitations: vulnerability to errors in judgment by researcher, low level of reliability and high level of biasness which subjects the research to inability to generalize research findings.

Snowball sampling technique

Snowball sampling is a special non-probability method used when the desired sample characteristic is rare. It may be extremely difficult or cost prohibitive to locate respondents in these situations. Snowball relies on referrals from initial subjects to identify additional subjects. This technique is preferable in sensitive areas like illegal hunting and illegal charcoal making. Though the costs of conducting research are lowered, snowball introduces biasness because the technique itself reduces the likelihood that the sample will be representative of the entire population.

Activity 2.15

Choose the relevant sampling techniques that will enable you to get the respondents in your proposed research. The formula is relevant for the sample size that will be obtained from probability technique.

Exercise 2.11

1. A combination of probability and non-probability sampling techniques is inevitable when dealing with research that focus on geographical challenges. Explain.
2. What are the advantages and disadvantages of conducting a research on a sample rather than the entire population?
3. Clearly, compare cluster and stratified sampling techniques.
4. "Multi-stage sampling technically integrates other sampling techniques to achieve its goal." Explain.

Data collection

Proper planned methods and tools for data collection is one among the means for ensuring accuracy, correctness, precision and validity of data to be collected. Data collection is a process of gathering information from all the relevant sources. With data collection, the researcher goes to the field and collects facts expected to answer the identified problem.

Data collection methods

Data may be collected from primary and secondary sources. Primary data are the data collected directly from the field by the researcher using the sense organs such as mouth, eye, ear, skin and nose. They are first-hand data collected through the use of various methods such as survey, observation, interview, focus group discussion and documentary review or measurement. Secondary data refers to data collected by the researcher from existing sources such as books, magazines, pamphlets, journal articles and other unpublished documents. These are second hand information obtained from already made material or documents.

Methods for data collection are defined depending on mode of conducting research and types of data collected. Data collection tools, also known as *instruments for data collection*, stand for various pre-designed means for capturing data in the field. The research tools are classified with respect to the data collection methods. The following are common methods for data collection:

Household survey

Household survey is a method of collecting data by administering a questionnaire to a sample of research respondents or participants to get information about a population through the sample. Despite being preferred in gathering data related to perceptions, opinions and ideas, surveys have several limitations such as less accuracy in measuring behaviour, too much demand for sample representativeness and low response rate.

The data collection instrument in the household surveys is called *questionnaire*. The questionnaire can be divided into structured and unstructured. *Structured questionnaire* refers to systematically prepared questions in a written form with a range of pre-determined responses (options/answer) that the respondent can select. The prepared questions with answers are called *closed-ended questions*. For the case of unstructured questionnaire, the same questions are composed but mostly dominated with *open-ended* questions. The following is an example of a structured questionnaire for household survey.

Example

Survey questionnaire

This research aims at collecting data to complete a research project as a requirement to successful completion of advanced level secondary school education. Therefore, the data collected from this research will strictly be for educational purposes and not any other uses.

Household's data

1. Are you the head of the household? Yes/No
2. What is the total number of members in your household? (1) Male…; (2) Female….; (1) grown-ups .... (>18 years); (2) children ..... (<18 years).
3. What is the level of education of the head of household? (1) Illiterate (2) Primary (3) Secondary (4) College (5) Other...........
4. How many members have been employed?............
5. What is the occupation of the household head? (1) Unemployed (2) Petty trade (3) Civil servant (4) Own business (5) Private employee (6) Other (please specify) ……………………………………………………………………………………
6. The average monthly income of the head of household: (1) Less than Tsh 50 000 (2) Tsh 50 001–100 000 (3) Tsh 100 001–500 000 (4) 500 001–1 000 000 (50 Greater than Tsh 1 000 000
7. How often do family members watch Television? (1) (>3 hours) (2) Everyday (3) Once a week (4) Once a month (5) Almost never.
8. Do you think the media has raised awareness on solid waste management? 1. Yes 2. No (if yes, cont. to Qn 9, if not, cont. to Qn 10).
9. Which mass media has been most useful for you in awareness raising? (1) Radio (2) Television (3) Newspaper (4) Social media (WhatsApp/Facebook /Instagram/ twitter/) (5) Mobile short message service (sms).
10. Where do you normally store your household waste?

Storage type	Frequency per week		
Pit/rubbish hole	1. Once ( )	2. Twice ( )	3. Thrice ( )
Waste bins	1. Once ( )	2. Twice ( )	3. Thrice ( )

Usually, structured questionnaires are tedious to prepare but easy to fill in. They are easy to analyse and more efficient when dealing with a large sample. On the contrary, unstructured questionnaires are easy to construct since they are dominated with open-ended questions but difficult for the respondents to fill in cases when they are required to do it on their own time, for example, those which are sent through mail. In addition, they pose difficulties in analysing although they provide rich data. Furthermore, their interpretation is subject to bias. The questionnaire can be administered to the respondents in different ways commonly through face-to-face interaction which is helpful in overcoming language barriers and influencing good response rates. However, it is time and resource consuming. Other methods are phone call and mailing or posting questionnaires in websites, but the methods are more challenging in terms of response rates and managing language barrier which has additional limitations related to the unguaranteed turn-up of answered questionnaire.

Interview

Key informant interview is mainly concerned with collecting qualitative data from skilled people on the topic not based on their educational knowledge and level, but their stake on the topic investigated. For example, if the research is about assessing the effectiveness of a given project, the research should involve people from the government or private institutions who, in one way or another, were involved in some activities during the implementation of the project. When dealing with the key informant interview, the *interview guides* are the main instruments used in collecting data from experienced people in the field with regard to the study conducted. Throughout, the data collected will solely be qualitative, challenging to analyse and cannot be generalized. The following is an example of the key informant interview guide for assessing the effectiveness of a project.

Example

Interview guide

1. Name of institution .... date.......................
2. What is your current position?
3. Are you a focal person in the climate change adaptation project implemented in village X?
4. Based on your participation in the project, what is your opinion on the impact of the project on livelihood and the environment?
5. With respect to your response in question 4, what is the most important factor that motivated people in the project area to participate in the activities?
6. Did the project sustainably empower the community? If so, how?
7. In your opinion, what are the main reasons for some villagers to drop the activities in the project?
8. What should be done to sustain the project activities?
9. In your opinion, was the project gender responsive?

Focus group discussion (FGD)

Focus group discussion is concerned with collecting qualitative data from a small sample, often homogeneous group of people within the studied population to explore their ideas on a particular topic based on their life experiences. The group should not be too large to allow everyone to have a chance to participate and should not take long time. The group should also not be very small to allow a wide range of ideas from group members. The method is recommended when the researcher aims at not only collecting interesting information, but also identifying issues and themes that are related to the objectives of the research conducted.

Generally, the focus group discussion is impractical in situations where the language barriers cannot be controlled, the researcher has little control over the situation; trust among the participants cannot be established; and free expressions and confidentiality cannot be ensured. In this method, checklist is used in data collection. Checklist is a set of logical pre-designed questions for data collection from focused group members in the field.

Some of the advantages of focus group discussion are as follows: Firstly, it can be conducted relatively quickly and easily; secondly, it allows flexibility in modifying the process and questions and it can explore different perspectives from the group participants. Some of its disadvantages include the fact that analysis of the collected data is time consuming and participants are not true representatives of the population from which they are drawn. For instance, if drawn from a village, they will not represent all villagers. Thus, the data will be biased and some members can be dominated by others. The following is an example of focus group discussion checklist.

Example

Focus group discussion checklist

1. What are your opinions about the ongoing water project management practices in your village?
2. Are you satisfied with the way the village water project management is done?
3. What is going well in the village with the project management?
4. What is not going well in the project management that you are dissatisfied with?
5. What kind of things would you like to see happening?
6. How about the issue of transparency among the water committee leaders entrusted with overseeing the project and collecting revenue? How about accountability? What do you think about these?
7. Some people have said that one way to improve X is to do Y. Do you agree with this? (Or, how do you feel about that?).
8. Are there other recommendations that you would like to make?
9. Are there any other things you would like to say before we wind up?
10. Can you say more about that? [Mention the aspect]
11. Can you give an example?
12. Jane says X. What is your opinion on that?

Observation method

Observation is a data collection method in which a researcher collects information in the field based on visualisation. Tools used for data collection are observation *guide*, *recording sheet* and *field notes*. The observation guide can be divided into semi-structured and structured observation guides. Normally, observation method and the associated tools are opted when there is a need for direct information to understand the ongoing behaviour, there is physical evidence, products, activities or outputs that can be observed and need for alternative data in cases other means of data collection seem to be impractical. The following is an example of a semi-structured observation guide for forest surveillance activity in a studied forest;

Example

Semi-structured observation guide

1. Who is taking part?
2. Number of participants ....
3. Nature of activity and forest surveillance ....
4. Time and location of the activity.
5. How is the activity organised?
6. What are the roles of participants and responsibilities?
7. Who makes decision and for who?
8. Are the resources made available to environmental surveillance team? For example, special equipment, mobile phones and means of transport for surveillance.

Although observation method is beneficial in collecting direct and real time data, it still has some limitations such as being observer-biased, and potentially unreliable. Moreover, there are interpretation and coding challenges. Again sampling can be a problem and it can be labour-intensive.

Transect walk

Transect walk is a team-based field walk along a defined path (transect) across the community or project area together with the local people often for the sake of collecting geographical data on various aspects by observing, asking, listening, watching and at the end producing a transect map or diagram. The data collection tools in this method include observation guide, recording sheet and field notes. Transect walks are usually preferred when the researcher is interested in collecting direct data by observing people, surroundings and resources in their natural settings. This data collection method demands good observation skills.

Activity 2.16

Identify the methods for data collection based on the variety of targeted population identified in Activity 2.12 then, develop the tools/instruments for data collection depending on the variety of methods of data collection you have identified.

Revision exercise 2

1. 'There is no need of conducting geographical research in Tanzania.' Comment on the statement.
2. Account for the following data collection methods used in field research.
   (a) Household survey
   (b) Interview
   (c) Focus group discussion
3. Discuss the roles of geographical research in daily life.
4. Describe the challenges encountered by a researcher when conducting a geographical research.
5. A research is a logical and systematic procedure. State the stages to be used or considered in conducting a geographical research.
6. In which circumstances would you opt to use:
   (a) Observation method
   (b) Household survey
   (c) Interview
   (d) Focus group discussion
7. Mr Rogwa is an environmentalist from Jozani village in Zanzibar. He receives some claims from his fellow villagers on the rate of deforestation from making charcoal and decides to conduct a research for his society.
   (a) Suggest the type of research which might be used by Mr Rogwa and give the reason.
   (b) Elaborate basic requirements to be considered by Mr Rogwa in conducting this research.
   (c) Explain four objectives for his research.
   (d) Identify three problems that Mr Rogwa may encounter in conducting his research.
8. Assume you have been appointed to assess the quality of the Form Four student's research proposals, explain the attributes that you will consider in the assessment.

Chapter Three

Geographical data analysis and interpretation

Introduction

Geographical data are used in different ways including people's understanding of the nature of the world and its dynamics. In this chapter, you will learn about data processing, analysis, presentation and interpretation of the results. The competences developed will enable you to analyse and interpret geographical information and phenomena for personal and community development. Furthermore, the competences gained will aid your understanding on various geographical phenomena and help you apply the insights obtained in your daily life.

Think about

Transforming data into meaningful insights that are useful in the practical world

Activity 3.1

1. Suppose you want to know the importance of weather information in everyday life.
   (a) Ask at least twenty members of your class or students from other classes in your school about how they understand the uses of weather information in your area;
   (b) Compile similar data into a tabular form;
   (c) Take into account the frequency of each use of weather information mentioned.
2. Provide answers to the following questions based on the information you have.
   (a) Which weather data are commonly used in your community? Give the reason(s) behind your response.
   (b) In your community, which weather information used the least? Describe your response(s) in detail.
   (c) Which sector/area relies more on weather information than the other(s) based on the information you have?
   (d) In light of the information you have, what impact does it have on the people's lives in your community?
   (e) Present your results before the class for broader discussion.

Geographical data processing, analysis, presentation and interpretation of results

After collecting geographical data or information of interest from the field, the researcher should process, analyse, present and make interpretation of the results.

Geographical data refers to data about objects, events or phenomenon that are attached to geographical location. It combines locational data and descriptive data. Locational data are presented on maps as points, lines or polygon depending on the geometric configuration of the respective objects, events or phenomenon. For example, roads, rivers, electric lines and railways are presented as lines. Features like houses, bore holes, wells and bus stops are presented as points, while plots, village boundaries, lakes and football ground area presented as polygons. Descriptive data characterises objects, events or phenomenon. Descriptive data are presented in tables with columns representing different data variables and rows representing individual objects, events or phenomenon. Locational data are acquired through land surveying GPS surveying and aerial photography while descriptive data are acquired through observation, survey, focus group discussion and interviews.

Processing of geographical data

This is the initial action following data collection. It entails filtering the data to minimize and correct any errors brought about by the process of data gathering. The researcher ought to review the quantity of data and identify any errors in a set of data and make necessary corrections or decide to discard the default data, if it is likely to affect the conclusions to be drawn from latter stages of the research process. Additionally, data processing helps to ensure that the questionnaire is complete. It is also useful in organising the collected data ready for analysis.

Analysis of geographical data

It is hard to interpret raw data and derive meaningful insights because they are inherently disorganized. For information to be meaningful, data analysis is necessary. Accordingly, the process of turning gathered data into information that has meaning can be referred to as *data analysis*. The objective of data analysis is to enable the researcher to summarize data, ascertain the relationship between variables, compare variables, find differences between variables, and forecast outcomes. The level of data analysis can be influenced by the type of data collected, the goal of the study, its scope, the experience of the researcher, and the type of research instrument employed in data collection. Geographical data analysis can broadly be categorised in quantitative and qualitative.

Quantitative geographical data analysis can be categorized into spatial or geometric, arithmetic and statistical analysis. Geometric data analysis involves measurement of position, distances and areas of mapped objects, events or phenomenon using techniques described in chapter five. Arithmetic data analysis involves adding, subtracting, multiplying or dividing numerical value of different variables of the same object, events or phenomenon. Statistical data analysis is further divided into descriptive and inferential. Descriptive data analysis is basic data analysis for summarising, characterising, presenting or associating data.

Example

Population data for Dodoma districts in Figure 3.1 is shown in Table 3.1

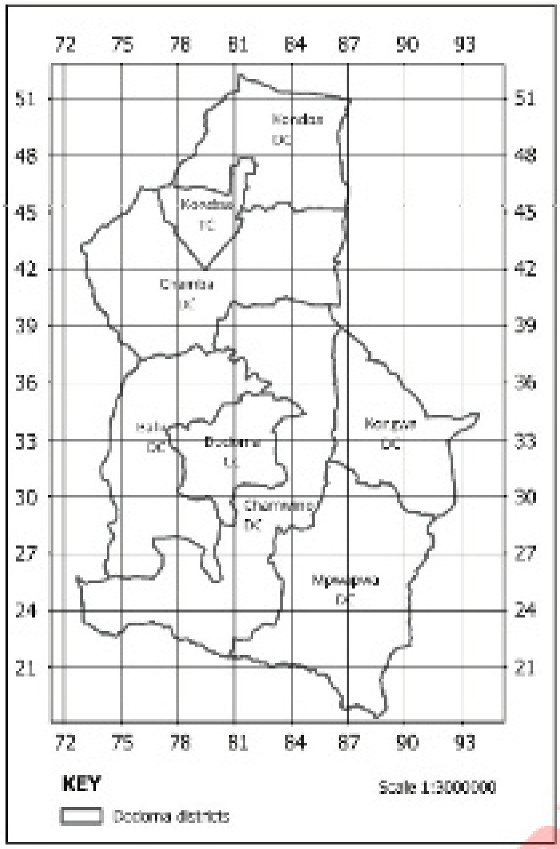


Figure 3.1: *The map of Dodoma districts*

Table 3.1: *Population data for Dodoma districts*

District	Population
Kondoa DC	244,854
Kondoa TC	80,443
Chemba DC	339,333
Bahi DC	322,526
Dodoma CC	765,179
Chamwino DC	486,176
Kongwa DC	443,867
Mpwapwa DC	403,247

Source: National Bureau of statistics (2022)

Compute:

(a) The area of each district in km².

(b) Population density.

Solution

The solution to this geographical problem involves geographical and numerical analysis. First, the area of each district is calculated by grid method through the following procedures:

i. The width and height of a grid are measured, in this case the width = height = 1cm;

ii. Convert the representative scale into statement scale as follows:

1: 3 000 000 = 1 cm: 3 000 000 cm

since 1km = 100 000 cm

? = 3 000 000 cm

1cm: 3 000 000 cm × 1 km/100 000 cm

Therefore 1cm = 30 km.

iii. Convert the width (W) and height (H) of a grid from map distance to ground distance using statement scale as follows:

Since 1cm = 30 km and W = H = 1cm, the ground distance for W = 30 km and H = 30 km.

iv. Calculate the area of a grid as;

Area = W x H = 30 km × 30 km

=900 km²

v. For each district in Figure 3.1, count the number of complete (n_o) and incomplete (n_i) grids as shown in Table 3.2:

Table 3.2

District	Population	n_c	n_i	n_t	Area (km^2)	Density (Population/km^2)
Kondoa DC	244,854	1	9	5.5	4,950	49.5
Kondoa TC	80,443	0	6	3	2,700	29.8
Chemba DC	339,333	1	15	8.5	7,650	44.4
Bahi DC	322,526	0	16	8	7,200	44.8
Dodoma CC	765,179	0	8	4	3,600	212.5
Chamwino DC	486,176	0	24	12	10,800	45.0
Kongwa DC	443,867	0	11	5.5	4,950	89.7
Mpwapwa DC	403,247	2	15	9.5	8,550	47.2

vi. Calculate the total number of grids (n_t) as;

$n_t = n_o + \frac{n_i}{2}$ and record in Table 3.2; and

vii. Calculate the area of each district (A) by multiplying the area of a grid by the total number of grids as shown in Table 3.2.

Finally, perform the numerical analysis to calculate the population density (PD) by dividing the population of each district by the respective area as shown in Table 3.2.

Example

Population data for hypothetical village in Figure 3.2 is shown in Table 3.3

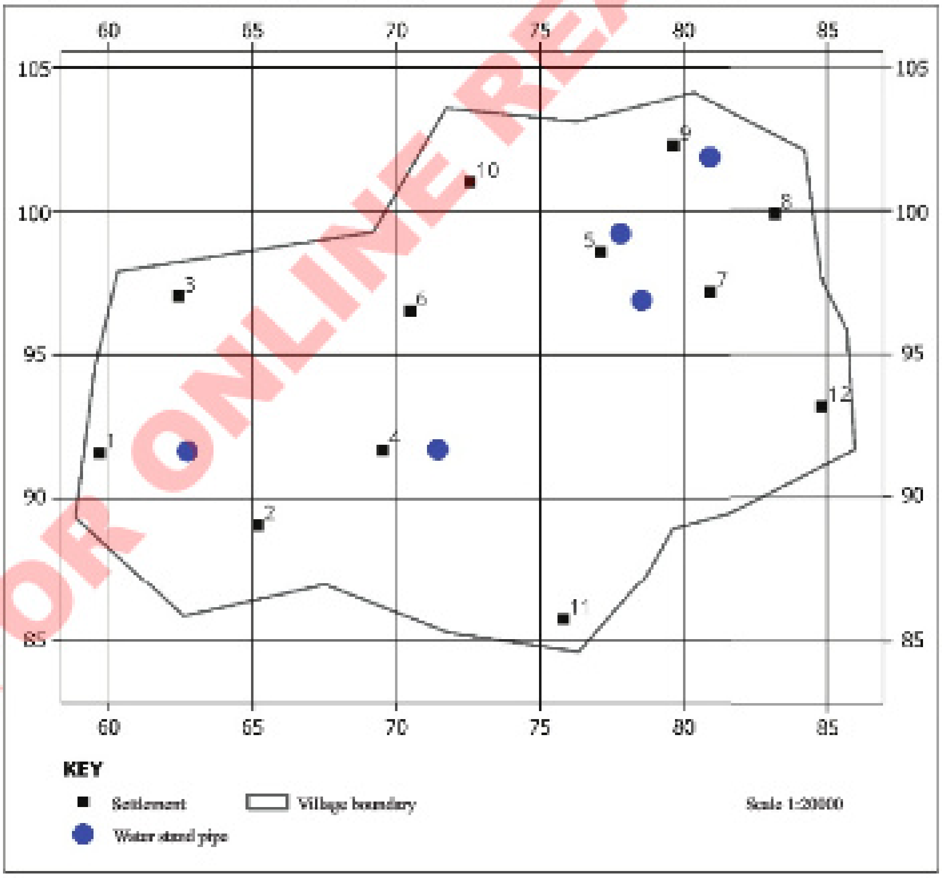


Figure 3.2: *Distribution of settlements and water stand pipe in the hypothetical village*

Table 3.3: Population data for hypothetical village

Settlement (ID)	Population
1	5,000
2	4,000
3	6,000
4	8,000
5	12,000
6	7,000
7	8,500
8	7,800
9	10,000
10	5,000
11	3,000
12	2,800

(a) Measure the distance from the centre of each settlement to the nearest water stand pipe.

(b) Calculate total population within 400 m from water stand pipe.

(c) Calculate the percentage of population within 400 m from water stand pipe.

Solution

The solution to this problem involves geometric and statistical analysis through the following steps:

i. Measure the distance from the centre of each settlement to the centre of the closest water stand pipe using a ruler and record from the shorter distance to the longer distance;

ii. Convert the representative scale into statement scale as follows:

1: 20 000 = 1cm: 20 000 cm

since

1m = 100 cm

? = 200 000 cm

$$\text{Therefore, } 1 \text{ cm} : \frac{20\,000 \text{ cm} \times 1 \text{ m}}{100 \text{ cm}}$$

1 cm : 200 m

iii. Use the statement scale to convert map distance to ground distance from each settlement to closest water stand pipe as shown in Table 3.1

1 cm : 200 m

Map distance : Ground distance (?)

∴ Ground distance =

$$\frac{\text{Map distance} \times 200 \text{ m}}{1 \text{ cm}}$$

iv. Determine the cumulative population as shown in Table 3.4

Table 3.4: Cummulative population at different ground distance

S/N	Settlement ID	Map distance (cm)	Ground distance (m)	Population (People)	Cumulative population (People)
1	5	0.5	100	12,000	12,000
2	9	0.7	140	10,000	22,000
3	4	1	200	8,000	30,000
4	7	1.2	240	8,500	38,500
5	8	1.5	300	7,800	46,300
6	1	1.5	300	5,000	51,300
7	2	1.8	360	4,000	55,300
8	6	2.5	500	7,000	62,300
9	3	2.7	540	6,000	68,300
10	10	2.8	560	5,000	73,300
11	11	3.7	740	3,000	76,300
12	12	3.7	740	2,800	79,100

Therefore, the population within 400 m is given by a cumulative population at ground distance that is less or equal to 400 m. In this case, the cumulative population of 55 300 is at the ground distance of 360 m.

The percentage of population within 400 m is calculated as:

$$\text{Percentage} = \frac{\text{Cummulative population at ground distance} \leq 400 \text{ m}}{\text{Cummulative population at longest ground distance}}$$

$$= \frac{\text{Cummulative population at 360 m}}{\text{Cummulative population at 360 m at the second 740 m}} \times 100$$

$$= \frac{55\ 300}{79\ 100} \times 100 = 69.6\%$$

Meanwhile, data analysis involving forecasting, contrasting two variables, and explaining the relationships between the variables often belong to the complex geographical data analysis. The complex form of geographical data analysis is also known as *inferential analysis* which is one among the advanced analyses in quantitative data.

Geographical qualitative data analysis typically entails a thorough examination of non-numerical data presented in the form of a text, pictures, graphics, symbols, and data on maps. Qualitative data can be analysed thematically through *content analysis*. Content analysis determines the presence, meaning, patterns and relationship of words, themes or concepts in qualitative data.

A variety of methods are available for performing data analysis. Both sophisticated and conventional methods are frequently used. The conventional method is a basic approach to data analysis that can be carried out with a calculator. It is frequently appropriate when dealing with small amounts of geographic data. Sophisticated data analysis calls for highly developed skills in both data analysis and related software. Analytical skills related to computer usage and the related software are required for this kind of analysis.

Descriptive statistical data analysis

Descriptive methods for quantitative data analysis are the measures of central tendency and measures of dispersion. The measure of central tendency is a single value that is used to describe a set of data by identifying the central position within the given set of data. It is the value that tends to lie centrally within the set of data arranged in the ascending order of magnitude, that is, from small to large values. Measure of central tendency enables one to compare two or more distributions pertaining to the same period of time or within the same distribution over time. For example, the average consumption of tea in two different geographical areas for two years, say 2022 and 2023, can be obtained by means of an average.

The most commonly used measures of central tendency for geographical data are ***mean, mode*** and ***median***. All measures of central tendency are useful. However, in different conditions some have become more appropriate than others. It is thus important to understand a good measure of central tendency. A good measure of central tendency possesses the following characteristics: easy to understand; simple to compute; scope of data utilisation; possibility of further algebraic treatment; possession of sampling stability and stability over the effect of extreme values. Measures of central tendency can be calculated for both individual and grouped data.

(a) *Mean*

Mean, also referred to as *arithmetic mean*, is the most popular measure of central tendency and may be defined as the value which we get by dividing the total of the value of various items in a series by the total number of items. Mean can be used in several ways, often in reporting the weather and climate, specifically for elements like temperature and rainfall. For instance, in Tanzania, we have been frequently hearing the reports and information related to the changes in mean annual temperatures and rainfall from sources such as the Tanzania Meteorological Authority (TMA). Thus, mean can be used to compute the central values of different variables and explain their importance on the phenomena in question, for example, the mean agricultural and livestock produce/yield.

Mean is categorised into arithmetic mean, geometric mean, harmonic mean and quadratic mean. In this book, only arithmetic mean has been covered.

(i) *The mean of ungrouped data*

This is obtained by diving the sum of values or scores of individual data by the number of individuals. The mean can be calculated from the sample data or entire population.

Procedures

(i) Find the sum of all data values or observation;

(ii) Divide the sum of the values of all individual by total number of individuals or items as sample mean $\bar{x}$ or population mean μ:

$$\text{Sample mean } (\bar{x}) = \frac{\sum_{i=1}^{n} x_i}{n}$$

$$\text{Population mean } (\mu) = \frac{\sum_{i=1}^{N} x_i}{N}$$

Where;

n = number of data values in the sample population

N = number of data values in the population

Σ = summation of

x_i = score, observations or value of individual/item (i)

Using the notation $\sum_{i=1}^{n} x_i$ we can write:

$$\sum_{i=1}^{n} x_i = x_1 + x_2 ... + x_n$$

Example:

1. Using population data for Dodoma districts in Table 3.1, calculate the arithmetic mean.

Solution

(i) First, sum the population of all Dodoma districts as;

$\sum x_i = x_1 + x_2 + x_3 + ...x_8$

= 244852 + 80443 + 339333 + 322526 + 765179 +488176 + 443867 + 408247

= 3092623

(ii) Then, divide the sum of the population of Dodoma districts by the number of Dodoma Districts as;

$$\bar{x} = \frac{\sum x_i}{n} = \frac{3092623}{8} = 386\,577.875$$

$= 386\,578$

2. Study the data given in Table 3.5 showing passengers transported by the TAZARA in '000 thousands from 2010 to 2016, and complete the sample mean.

Table 3.5: *Passengers transported by the TAZARA in '000 thousands from 2010 to 2016*

Year	2010	2011	2012	2013	2014	2015	2016
Passengers in '000 thousands	758	414	678	654	287	327	440

Source: Ministry of Works, Transport and Communication (2016)

Solution:

$$\text{Formula } \bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$$

$$\bar{x} = \frac{758+414+678+654+287+327+440}{7} = \frac{3\,558}{7}$$

$$\bar{x} = 508.2857 \approx 508$$

Therefore, this means that on average, the passengers transported by TAZARA per year were 508,000.

For data set with frequencies

The mean of ungrouped data with frequencies (Table 3.6) can be calculated by using similar procedures.

Table 3.6: *Scores of a given sample*

x_i	Frequency (f)
1	3
2	4
3	6
4	2
5	5

Procedures

(i) Multiply the data value (x_i) with the respective frequency (f) to get (fx).

(ii) Sum the product (fx) to get ($\sum f x_i$)

(iii) Sum the frequency to get ($\sum f$)

(iv) Divide the sum of product ($\sum fx$) by the sum of frequency ($\sum f$) to get the mean.

For example: Use the data in Table 3.6 to calculate the mean of ungrouped data. The first 3 steps are carried out in Table 3.7. The product fx is determined in column three. The sum of frequency $\sum f$ and product of $\sum fx$ are determined in the last row.

Table 3.7: *Score for a given sample*

x	f	fx
1	3	3
2	4	8
3	6	18
4	2	8
5	5	25
	$\sum f = 20$	$\sum fx = 62$

Finally, the mean ($\bar{x}$) for geographical data with frequencies is calculated as;

Where; $\bar{x} = \frac{\sum fx_i}{\sum f}$

Substitute the values $\sum fx = 62$ and $\sum f = 20$

$$\bar{x} = \frac{62}{20}$$

$$= 3.1$$

Therefore; the mean for the score of the given sample is 3.1

Mean of grouped data

This is useful when someone has a wide range of data which are supposed to be grouped into classes to facilitate further analysis. Mean in the grouped data can be computed by using two methods, namely; assumed mean method and direct method (shortcut method).

Calculating mean by direct method

Direct method involves calculation of midpoint of each class and the product of mid point value and the respective frequency.

Example:

Find the mean of population data in Table 3.8 for town 'K'.

Table 3.8: *Population data for town 'K'*

Class interval	Frequency (f)
0 – 2	2
3 – 5	5
6 – 8	6
9 – 11	2
12 – 14	2
15 – 17	4
18 – 20	6

Procedures

(i) Find the midpoint/classmark of each of the class interval (x_i) as shown in Table 3.9.

(ii) Find the product fx_i as shown in Table 3.9.

(iii) Find the sum of frequency $\sum f$ and products $\sum fx_i$ as shown in Table 3.9.

Table 3.9: *Midpoint and sum of frequency of population data for town 'K'*

Class interval	Frequency (f)	Mid-point (x_i)	fx_i
0 – 2	2	1	2
3 – 5	5	4	20
6 – 8	6	7	42
9 – 11	2	10	20
12 – 14	2	13	26
15 – 17	4	16	64
18 – 20	6	19	114
TOTAL	$\sum f = 27$		$\sum fx_i = 288$

(iv) Calculate the mean of grouped population data by dividing the sum of product $\sum fx_i$ by the sum of frequency $\sum f$ as follows:

$$\bar{x} = \frac{\sum_{i=1}^{n} fx_i}{\sum f}$$

$\sum fx_i = 288$, $\sum f = 27$

$$\bar{x} = \frac{288}{27}$$

$= 10.6666$

Therefore, the central value for the population data of the given sample is 10.67.

Calculating mean by assumed mean method

When the values or scores under observation are extremely large and in fractions, the use of the direct method becomes inconvenient. As a result, the use of the assumed mean method can be done. The method uses the concept of the arbitrary or assumed mean.

Example:

Find the mean of school Y students' scores as shown in Table 3.10 in Geography subject using the assumed mean method.

Table 3.10: *School Y students' scores in Geography subject*

Scores	Frequency (*f*)
0 – 10	4
10 – 20	8
20 – 30	11
30 – 40	15
40 – 50	12
50 – 60	6
60 – 70	2

Procedures

(i) Find the midpoint/class mark of each of the class interval (x);

(ii) Assume one value as a mean. Based on the given data in Table 3.10, the largest f is on intervals 30-40, which also happens to be almost in the centre of the distribution; 35 is taken as assumed or arbitrary mean.

(iii) Subtract the arbitrary mean from each value of mid-point and the resultant value is shown in column d of Table 3.11;

(iv) Multiply each d by respective frequencies (f) to get (fd) (Table 3.11);

(v) Find the algebraic sum of fd and the sum of f. Sometimes $\sum fd$ can be positive or negative:

Table 3.11: *Assumed mean of school Y students' scores in Geography*

Scores	Mid-point	f	d	fd
0 – 10	5	4	-30	-120
10 – 20	15	8	-20	-160
20 – 30	25	11	-10	-110
30 – 40	35	15	0	0
40 – 50	45	12	10	120
50 – 60	55	6	20	120
60 – 70	65	2	30	60
		$\sum f = 58$		$\sum fd = -90$

(vi) Divide the sum of product fd by the sum of $\sum f$ to get the frequencies $\frac{\sum fd}{\sum f}$; and

(vii) Add the correction factor to the assumed mean to get the actual mean as $\bar{x} = A + \frac{\sum fd}{\sum f}$

Where:

A = arbitrary or assumed mean

f = frequency

d = deviation from the arbitrary or assumed mean

$\sum f$ = number of data values in the population

Assumed mean (A) = 35; the correction factor for the difference between the actual mean and the assumed mean ($\sum fd$) = –90 and $\sum f$ = 58.

$$\bar{x} = 35 + \frac{(-90)}{58}$$

$$= 35 + (-1.55)$$

$$= 33.45$$

Therefore, the mean scores for school Y students in Geography subject is 33.45

Advantages and disadvantages of mean

The use of mean in analysing and summarising geographical data has both advantages and disadvantages. The main advantages include the fact that mean is easy to calculate, especially in small data set; it includes all values in the distribution; it is useful for summarising geographical data and comparing geographical information. It is also widely understood compared to other averages and suited to further analysis.

The main disadvantages include the fact that the mean is highly distorted by *outliers*. Outliers refer to the extremely high or low values in the observation. It is also impossible to locate the mean by inspection as in the case of mode and median. The value of mean will be effective only if the frequency is normally distributed. Otherwise, in case of skewness, the results become ineffective.

(b) *Median*

Median is value of the middle item. It is the value of the middle item for a set of geographical data that has been arranged in order of magnitude or the point below and above 50% of the scores in distribution (the mid-point in a distribution). Median can be determined for grouped and un-grouped data.

Median for ungrouped geographical data

Procedures

(i) Arrange data in ascending or descending order.

(ii) If the total number of items is in odd, add one (1) to the total number of observations (n) then divide by two (2) to acquire the position of median.

(iii) The value of the median for un-grouped data is given by the expressions below:

Median = Value of the $\left(\frac{n+1}{2}\right)^{th}$ term in a ranked data set.

Note: the expression is purposely for finding the position of the mid value.

(iv) If the total of the items (values) is even, median is obtained by adding the two central values and dividing the sum by 2.

Examples

1. Study the data in Table 3.12 which shows production of cashewnut in '000 tonnes in Tanzania from 2012 to 2016, and find the median.

Table 3.12: *Production of cashew-nut in Tanzania*

Year	2012	2013	2014	2015	2016
Cashew nut production in tonnes	160	128	130	198	155

Source: National Bureau of Statistics (2018)

Solution

The values of production are arranged in ascending order = 128, 130, 155, 160, 198
$n = 5$, then

The $\left(\frac{n+1}{2}\right)^{th}$ value $= \frac{5+1}{2} = 3$ this means the mid value is on the 3rd position of the data set.

That is, the median is 155 000 tonnes which means the mid value of production throughout the five years of cashew-nut production.

2. Study the data in Table 3.13 showing the total monthly rainfall recorded in Tanzania in the year 2016 and find the median.

Table 3.13: *Total monthly rainfall recorded in Tanzania in the year 2016*

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly total rainfall (mm)	191.8	131.2	14.0	213.6	41.1	9.2	2.2	8.3	14.1	27.8	64.6	66.6

Source: *Tanzania Meteorological Agency (2016)*

Solution

Arrange the value of rainfall in ascending order.

That is 2.2, 8.3, 9.2, 14.0, 14.1, 27.8, 41.1, 64.6, 66.6, 131.2,191.8, 213.6

The position of the mid value is given by the expression $\left(\frac{n+1}{2}\right)^{th}$ value $= \frac{12+1}{2}$ $= 6.5$ this means the position of the mid value is at 6.5 position. In this case, mid value is obtained by finding the mean of the 6th and 7th (the two middle) values in the data set. The 6th value is 27.8 and the 7th is 41.1 =

$$\frac{27.8+41.1}{2}=\frac{68.9}{2}=34.45=34.5\text{ mm}$$

Therefore, the median value for rainfall is 34.5 mm which is the mid value of the rainfall in twelve months.

Median for grouped data

Use the given data in Table 3.14 which shows the distribution of students' scores for school 'Y' in Tanzania to calculate median of grouped data.

Table 3.14: *Distribution of students' scores for school "Y" in Tanzania*

Class interval	Frequency (f)
0 – 4	2
5 – 9	6
10 – 14	10
15 – 19	8
20 – 24	4

Procedures

(i) Construct the cumulative frequency distribution.

Table 3.15: *Cumulative frequency of students' scores for school "Y" in Tanzania*

Class interval	Frequency (f)	Cumulative frequency (cf)
0 – 4	2	2
5 – 9	6	8
10 – 14	10	18
15 – 19	8	26
20 – 24	4	30

(ii) Decide the class that contain the median. Median class is the first class with the value of cumulative frequency equal to or at least $\frac{n}{2}$.

(iii) Find the median by using the following formula:

$$\text{Median} = L_m + \left(\frac{\frac{n}{2}-cf}{f_m}\right)i$$

Where;

n = total frequency

cf = cumulative frequency before median class

f_m = frequency of the median class

i = class interval or class width

L_m = lower boundary of the median class

Note: Lower boundary of each class is calculated by subtracting half of the gap value from the class lower limit. For example, $10 - 0.5 = 9.5$. 0.5 is used because the gap value is 1.

$$\text{Median} = 9.5 + \left(\frac{\frac{30}{2} - 8}{10} \right) 5$$

$$= 9.5 + \left(\frac{15 - 8}{10} \right) 5$$

$$= 9.5 + \left(\frac{7}{10} \right) 5$$

$$= 9.5 + 3.5$$

$$= 13$$

Therefore, the mid value for the score is 13.

Advantages and disadvantages of median in geographical data analysis

The main advantages of the use of median in geographical research data are: one, it is easy to understand by considering the half way point of the data set under observation. Therefore, it is suitable for distributions with extreme values. Secondly, median is not distorted by the extreme value(s) in distribution. Thirdly, median is relevant in skewed data distribution.

The advantages above notwithstanding, median has some limitations such as unsuitability for further mathematical treatment or advanced processing; not being based on all values under observation; and being highly affected by the fluctuation of sampling as opposed to mean. Furthermore, median is not reliable in testing geographical hypothesis, particularly in advanced levels of the field of Geography.

(c) *Mode*

Mode is the most frequent score in a distribution of geographical data. The mode of a set of data is the observation which occurs most frequently. It is also defined as a point of maximum frequency density in the distribution. Mode is presented by the highest column (s) in the histogram. In some data set, the mode may not exist, while in other data sets, two or more modes may exist. The occurring mode can be either uni-modal, bimodal or multi-modal.

Mode is one of the useful averages in the field of climatology as it can be used in the classification of weather patterns in various geographical areas. In case of Tanzania, many areas have single rainfall peak per year called uni-modal areas while the rest of areas receive two peaks of rainfall called bimodal areas. Some of the areas that receive bimodal rainfall include Dar es Salaam, Musoma, Morogoro, Tanga, Kagera and some parts of Mwanza region. There are also areas that receive three seasonal rainfall per year, such a pattern is called trimodal.

Mode for the ungrouped data

Uni-modal of ungrouped data occurs when there is one (1) mode value in a distribution. For example in 4, 5, 6, 6, 7, 8, 9, 10, 10, 10,

Mode is 10 because it has occurred three times.

Bimodal is when a set of data has two modes, for example, 1, 2, 3, 3, 4, 4, 4, 5, 5, 6, 6, 6, 11. Here the modes are 4 and 6. This is because they have both occurred three times.

Multi-modal exists when the data set has more than two modals, for example 1, 3, 5, 8, 9, 2, 4, 8, 7, 20, 5, 6, 2, 1, 2, 3, 4, 5, 5, 6, 7, 8, 8, 9, 20, 2.

In the data set above, the modes are 2, 5 and 8. This is because these numbers have more occurrences than others, which is three times.

Mode for the grouped data

In grouped data, mode can be calculated by the following formula:

$$\text{Mode} = L_m + \left(\frac{t_1}{t_1 + t_2}\right)i$$

Where;

L_m = lower limit of the modal class

t_1 = frequency of the modal class minus frequency before the modal class; that is, the difference between the frequency of modal class and frequency of premodal class.

t_2 = frequency of the modal class minus frequency after the modal class, that is, the difference between frequency of modal class and frequency of post modal class.

i = class width or the size of the class interval.

Example:

Study the Table 3.16 and then find the mode.

Table 3.16: *Distribution of scores*

Class interval	Frequency
40 – 44	7
45 – 49	8
50 – 54	11
55 – 59	10
60 – 64	7

Solution

Given

L_m = 49.5,

t_1 = (11 – 8)

= 3

t_2 = (11 - 10)

= 1

i = 5

Using the formula for the mode:

$$\text{Mode} = 49.5 + \left(\frac{3}{3+1}\right)5$$

$$= 49.5 + \frac{3}{4} \times 5$$

$$= 49.5 + 3.75$$

$$= 53.25$$

Therefore, mode is 53.25

Estimating a mode from a histogram

Mode from grouped data can be derived from histogram. For example, using score distribution from Table 3.16, mode can be determined from a histogram following the procedures below:

Procedures

(i) Draw a histogram;

(ii) Identify the modal class represented by the tallest bar;

(iii) Draw the cross lines using a solid red line as shown in Figure 3.3;

(iv) Draw a perpendicular line using a doted line from the intersection of the two solid lines until it touches the horizontal axis as shown in Figure 3.3; and

(v) Read the mode at the intersection of the perpendicular line with the horizontal axis.

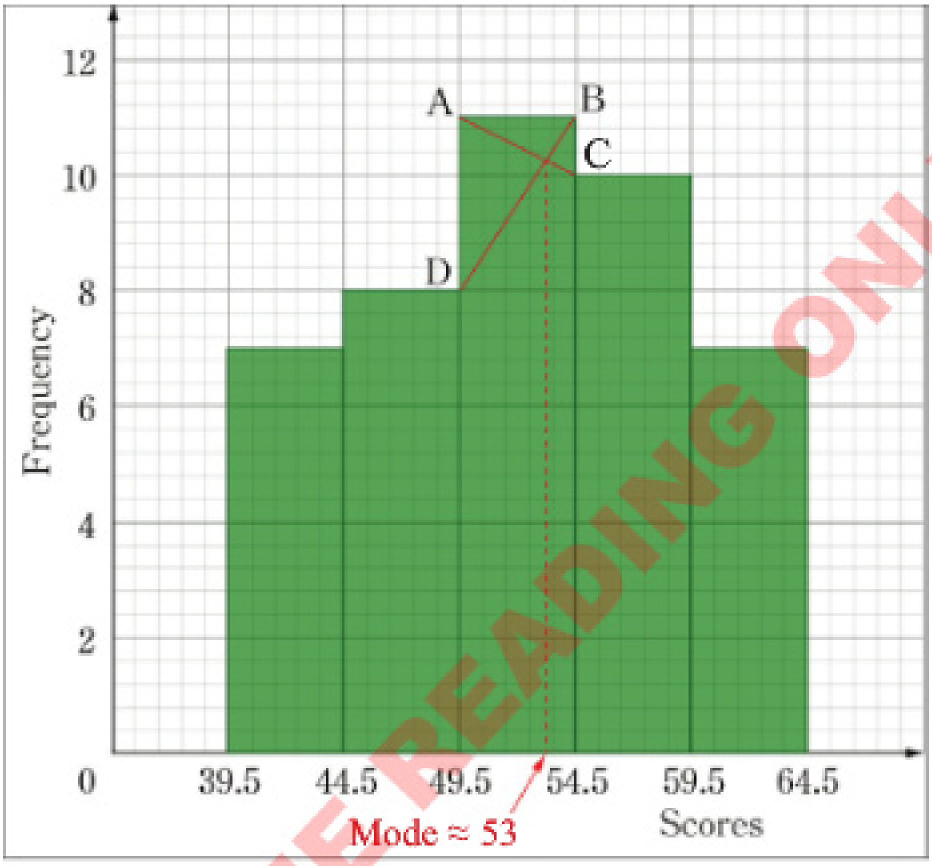


Figure 3.3: *Estimating a mode from a histogram*

Advantages and disadvantages of a mode in geographical research

Mode is of paramount importance in geography. Some of its advantages are: one, it is not affected by the occurrence of a few extreme values under the distributions; two, it determines various phenomena such as the magnitude of agricultural production or the trend of commodities. In addition, mode is the only average to be opted for categorical data. Moreover, mode is easy to read and interpret in the given data; easy to understand, calculate and interpret. On the other hand, mode is disapproved for various limitations. Firstly, it is not strictly defined in such a way that it is unstable with large samples. Secondly, it is not based on all data values under observation; and thirdly, it is not suitable for further mathematical treatment. The existence of mode when data are the same in some of the distributions discourages its use in analysis of data and its usefulness is less common in advanced geographical research. Compared to mean, mode is severely affected by the fluctuation of sampling.

Relationship between different measures of central tendency for geograhical data

The various measures of central value give us one single figure that represents the entire data. But the average alone cannot adequately describe a set of observations, unless all observations are the same. Measures of central tendency often portray some relationships between them. The relationship is determined by the nature and pattern of the distribution of geographical data in the sample or population. Normally, the relationship between mean, median and mode of a population generates symmetrical and skewed curves.

When the population mean, median and mode are all located at the centre, they result to a symmetrical bell-shaped curve called normal distribution curve, which can be divided into two equal halves (one half is a mirror image of the other) as shown in Figure 3.4(a). In this, case mean = median = mode. In case the distribution is skewed to the right, it is positive skewness in which the longer tail is on the right side, then mean > median > mode. Generally, income distribution is skewed to the right where a large number of families have relatively low income and only a small number of families have extremely high income. In this case, the mean is pulled up by the extreme high incomes and the relation among these three measures is as shown in Figure 3.4(b) where mean > median > mode.

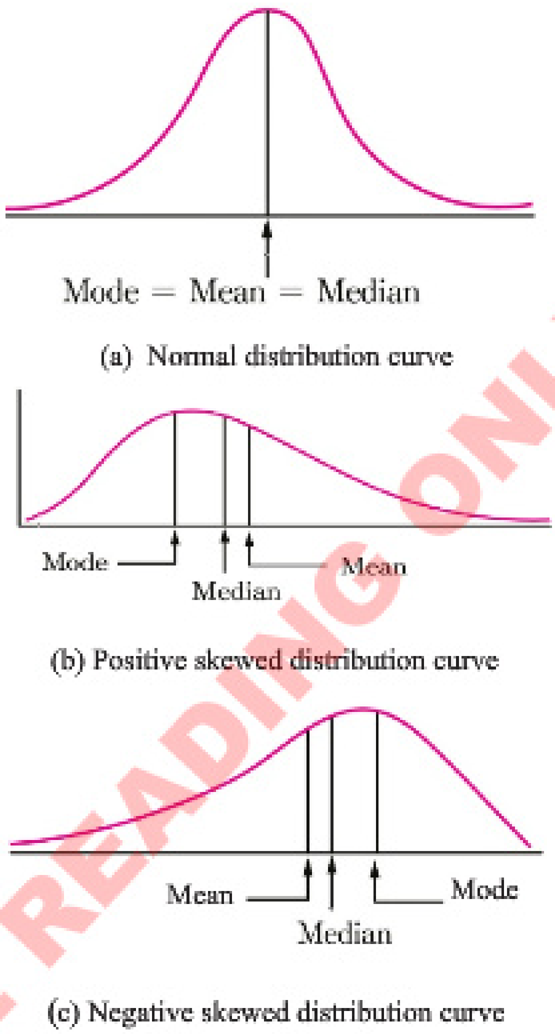


Figure 3.4: *Types of distribution curves*

When a distribution is skewed to the left, it is negative skewness in which the tail is on the left side. Thus mode> median> mean. In this case, the mean is pulled down below the median by extremely low values as shown in Figure 3.4(c).

The general limitations of measures of central tendency in geographical data

On summarising data, various measures of central value give us one single figure that represents the entire data from the sample or population being studied. It should be noted that the average alone can not adequately describe a set of observations, unless all the observations are the same. Mean, median and mode fall short of indicating the extent of dispersion or variability in distribution. Dispersion and variability are important because they enable us to understand the pattern of the data, which is limitedly explained by the measures of central tendency. In some cases, two or more distributions can have the same central value yet there can be a wide discrepancy in the formation of distribution. In this ground, measures of dispersion become helpful for understanding characteristics of distribution.

Exercise 3.1

1. Why is average called a measure of central tendency?
2. Average has its own peculiar characteristics. It is difficult to say which average is the best. Explain with examples.
3. Under which conditions is the median more suitable than other measures of central tendency?
4. Find the mean, median and mode of the following data graphically, then comment on the obtained values of the calculated central tendency.

Class interval	0–10	10–20	20–30	30–40	40–50	50–60	60–70
Frequency	4	18	30	42	24	10	3

5. Explain the geographical estimates resulting from geographical data analysis.
6. Explain the usefulness of geographical estimates in relation to geographical phenomena.

Measures of dispersion in geographical research

The degree to which numerical data tend to spread about an average value is called *dispersion* or variation of data. The measure of dispersion is also known as measure of variation or spread. Two distributions can have identical means and medians, yet their difference can be identified by using measures of dispersion. For example, in the distribution of data set A: 18, 20, 25, 35, 39 and B: 2, 3, 25, 30, 75, the mean in both of these distributions is 27 and the median in both is 25. However, the distribution differs greatly. Just by observing the distribution in A, the scores are closer and tend to cluster around the mean of distribution while in B the scores are much more spread out. The difference of two or more distributions is termed by the geographical researchers as variability.

Measures of dispersion show how spread out or dispersed the data are, something that cannot be achieved by the measures of central tendency. As a result, the central tendency becomes less appropriate for some analysis. For example, a statement that by 2014 the mean annual salary for public servants in country X was 200 million, hides information on the fact that some workers earned far less than the mentioned amount and others earned more than 200 million. Therefore, knowing the mean is insufficient to understand the entire distribution of workers' salaries. This limitation pave way for the need of applying other measures that are capable of describing the spread or variability that exists within the distribution of a given data set. The commonly used measures of dispersion are range, mean deviation, variance and standard deviation.

(a) *Range*

Range is the difference between the smallest and the largest value in the distribution of geographical data. The overall range represents the distance between the highest and lowest scores in the distribution.

Range for ungrouped data

Range can be calculated by subtracting the smallest value (S) from the largest value (L) in the distribution. Range takes into consideration the extreme values in a data set.

Example:

Study the following distribution of data and calculate the range: 2, 3, 5, 7, 14, 15, 24, and 25.

Solution:

From the given data the largest value is 25 and the smallest value is 2.

The range = Largest value (L) – smallest value (S) = 25 – 2 = 23

Therefore, the range = 23

The range for the grouped data

This is obtained by using the differences between upper limit, lower limit and mid-point of largest and smallest class interval.

Using data in Table 3.17, find the range.

Table 3.17: *The distribution of scores*

Scores	Frequency
15 – 19	2
10 – 14	1
5 – 9	1
0 – 4	2

Solution:

From Table 3.17, the range is determined as:

(a) Range = Highest upper class limit – Lowest upper class limit
$19 - 4 = 15$ Range = Highest lower class limit – Lowest lower class limit
$$15 - 0 = 15$$

(b) Range = Highest upper real limit – Lowest upper real limit
$$19.5 - 4.5 = 15$$
Range = Highest lower real limit – Lowest lower real limit
$$14.5 - (-0.5) = 15$$
$$= 15$$

(c) Range = Midpoint of largest class interval – Midpoint of smallest class interval.

The largest class interval is 15 – 19 and the smallest class interval is 0 – 4.

The midpoint of the largest class interval (L)$=\frac{15+19}{2}=\frac{34}{2}=17$

The midpoint of the smallest class interval (S) $=\frac{0+4}{2}=\frac{4}{2}=2$

$= 17 - 2 = 15$

Coefficient of range in geographical data

Coefficient of range is the ratio of the difference between the highest and lowest value of frequency to the sum of the highest and lowest value of frequency. It is a relative measure of the distribution based on the range of any given data set.

The coefficient of range is calculated by the formula:

$$\text{The coefficient of range} = \frac{\text{Highest value in frequency (L)} - \text{Lowest value in frequency(S)}}{\text{Highest value in frequency(L)} + \text{Lowest value in frequency(S)}}$$

The coefficient of range is more appropriate for the purposes of comparison.

Example

Study Table 3.18 and calculate the coefficient of range separately.

Table 3.18: *Distribution of scores for two sets in class "H"*

Set 1	8	10	20	9	15	10	13	28
Set 2	30	35	42	50	32	49	39	33

Solution:

As shown in calculation, range of the two sets of data are the same:

Set 1: $28 - 8 = 20$

Set 2: $50 - 30 = 20$

Coefficient of range in Set 1 is:

$$\frac{28-8}{28+8}=0.55$$

Coefficient of range in Set 2 is:

$$\frac{50-30}{50+30}=0.25$$

The coefficient of range tells the degree of dispersion in a set of data. The larger the value, the higher the dispersion.

Advantages and disadvantages of the range in geographical research

Range is opted because it is easy to calculate and understand. It also gives a quick estimate of variability in distribution. Regardless of the simplicity of obtaining range just by considering only two values of a set of data, it is important to many fields and individuals, including geographers in many ways. Range is used to get a quick understanding of the variability or a set of data. In case of a small sample, range is considered as a sufficient measure of variability. It is often used in quality control where a continuous check on the variability of raw materials or finished products is required.

Range is also an appropriate measure in weather forecast. For example, in daily reports on weather forecast from Tanzania Meteorological Authority (TMA), we normally hear of maximum and minimum temperatures, rainfall, wind, and humidity and sunshine. Such geographical information may seem useless to some people but it may be important for those with plans and activities that need updates on weather to make appropriate decisions.

Range has some drawbacks. It is highly affected by the extreme values in a distribution, hence it cannot depict the nature of dispersion of items in a distribution. Range can mislead the interpretation of data if there were some errors during collection of raw data. It is also based on only two items, hence does not cover all the items in a distribution. The other weakness is its susceptibility to wide fluctuations from sample based on the same population. It fails to give any idea about the pattern of distribution; and in the case of open-ended distributions, it is impossible to compute range.

(b) *Mean deviation (MD) for geographical data*

The mean deviation is also known as the *average deviation*. Mean deviation denotes the amount by which individual value deviates from the mean in irrespective of sign (+ or −). The negative and positive signs are ignored during computation since the deviations are always equal, irrespective of their signs. It is the average difference between various measurements and the mean.

Mean deviation for ungrouped data

The formula for computing the mean deviation for ungrouped data is given below.

$$\text{Mean deviation} = \frac{\Sigma\left|x_i - \bar{x}\right|}{n}$$

Where:

$\left|x_i - \bar{x}\right|$ = It is the absolute difference between each value and the mean.

n = the total number of observations

$\sum$ = summation of

x = observation or values

Procedures

(i) Compute the mean of the given observations;

(ii) Find the individual deviation by subtracting the mean from each of the given observations as shown in Table 3.19;

(iii) Sum the absolute deviation; and

(iv) Divide the resulting sum by the total number of observations or items.

Example:

The distribution of scores for class 'D' are 2, 3, 4, 5, and 6. Compute the mean deviation.

Solution

$$\bar{x} = \frac{2+3+4+5+6}{5} = \frac{20}{5} = 4$$

Table 3.19: *Distribution of scores for class 'D'*

x_i	$\bar{x}$	$\lvert x_i - \bar{x} \rvert$
2	4	2
3	4	1
4	4	0
5	4	1
6	4	2
$n = 5$		$\sum \lvert x_i - \bar{x} \rvert = 6$

Thus, mean deviation (MD)

$$= \frac{\Sigma \lvert x_i - \bar{x} \rvert}{n} = \frac{6}{5} = 1.2$$

Therefore, the mean deviation is 1.2

Mean deviation for grouped data

The formula for computing the mean deviation of grouped data is given below.

$$\text{MD} = \frac{\Sigma f \lvert x_i - \bar{x} \rvert}{\Sigma f}$$

Table 3.20: *Scores for form five students in Benbella Girls Secondary School*

Scores	Frequency *f*
20–29	2
30–39	3
40–49	10
50–59	13
60–69	3
70–79	2
80–89	1

Procedures

(i) Calculate the class mark x_i for each interval as shown in Table 3.21;

(ii) Find the product (fx) frequency (f) and class interval (x_i) as shown in Table 3.21;

(iii) Calculate the sum of frequency $\sum f$ and sum of $\sum fx_i$ as shown in Table 3.21.

(iv) Using $\sum fx$ and $\sum f$ from Table 3.21, calculate the mean $\bar{x}$ as;

$$\bar{x} = \frac{\sum fx_i}{\sum f}$$

$$= \frac{1733}{34}$$

$$= 50.9$$

Table 3.21: *Geography subject scores for form five students in Benbella Girls Secondary School*

Scores	f	Class mark (x_i)	fx_i	$\bar{x}$	$\lvert x_i - \bar{x} \rvert$	$f \lvert x_i - \bar{x} \rvert$
20–29	2	24.5	49	50.9	26.4	52.8
30–39	3	34.5	103.5	50.9	16.4	49.2
40–49	10	44.5	445	50.9	6.4	64
50–59	13	54.5	708.5	50.9	3.6	46.8
60–69	3	64.5	193.5	50.9	13.6	40.8
70–79	2	74.5	149	50.9	23.6	47.2
80–89	1	84.5	84.5	50.9	33.6	33.6
Total	$\sum f = 34$		$\sum fx = 1733$			$\Sigma f \lvert x - \bar{x} \rvert = 334.4$

(v) For each class, calculate the deviation $(x_i - \bar{x})$ of class mark (x_i) from the mean $(\bar{x})$ as shown in Table 3.21;

(vi) Calculate the product $\left(f\left|x_i-\bar{x}\right|\right)$ of frequency (*f*) and absolute deviation $\left|x_i-\bar{x}\right|$ as shown in Table 3.21;

(vii) Calculate the sum of the product $\sum f\left|x_i-\bar{x}\right|$; and

(viii) Calculate the mean deviation (MD) using $\sum f\left|x_i-\bar{x}\right|$ and $\sum f$ from Table 3.17 as

$$MD = \frac{\Sigma f\left|x_i-\bar{x}\right|}{\Sigma f} = \frac{334.4}{34} = 9.84$$

Therefore, the mean deviation of the scores is 9.84

Advantages and disadvantages of mean deviation in geographical research

The use of mean deviation in geography has a number of advantages. First of all, it is simple to understand and calculate. It also takes into consideration all the dataset under observation and it is less affected by the extreme values. Since the deviations are taken from the central value, it is possible to make a meaningful comparison of the setup of different distributions.

On the other hand, mean deviation has the following weaknesses: it falls short of allowing further algebraic treatment; and it sometimes fails to give accurate results. Mean deviation gives best results when deviations are taken from the median rather than the mean. In a series, with wide variations in items, mean deviation is not a satisfactory measure; and from mathematical perspectives, the method is wrong for it disregards the algebraic signs when deviations are taken from the mean. Because of these limitations, mean deviation is seldom used in geography studies. Such limitations pave the way for better measures of variability which are often used in geographical studies.

(c) ***Variance***

Population variance often denoted by σ^2 is the mean of the squares of the differences between each data value and the mean. For the case of the sample, variance is often denoted by s^2. Variance is also a measure of the spread between given scores or data set. It measures the distance of each number from the mean and from one number and the other.

Therefore, the large variance indicates that scores are far from each other as well. Variance can be calculated for ungrouped and grouped data. For ungrouped data, variance can be calculated using the formula below:

$$\sigma^2 = \frac{\sum(x-\bar{x})^2}{N}$$

Where:

σ^2 = Variance from sample
$\bar{x}$ = Mean of sample
N = Population size

Procedures

(i) Calculate the mean $(\bar{x})$.

(ii) Find the deviation from the mean $(x-\bar{x})$.

(iii) Square the deviations from the mean $(x-\bar{x})^2$.

(iv) Sum all the square deviations and apply the formula.

Example

The distribution of scores in a class of Practical Geography are 2,7,3,12, and 9. Calculate variance.

Solution

$$\bar{x} = \frac{2+7+3+12+9}{5} = 6.6$$

Table 3.22 *Distributions of scores in a class of Practical Geography*

x	$\bar{x}$	$(x-\bar{x})$	$(x-\bar{x})^2$
2	6.6	– 4.62	21.16
7	6.6	0.4	0.16
3	6.6	–3.6	12.96
12	6.6	5.4	29.16
9	6.6	2.4	5.76
			$\sum_{i=1}^{n}(x-\bar{x})^2 = 69.2$

(v) Square the deviation from the mean as shown in Table 3.18.

(vi) Sum all square deviations as shown in Table 3.18 and calculate the stated deviation as follow:

$$\sigma^2 = \frac{\sum(x-\bar{x})^2}{N}$$

$$\sigma^2 = \frac{69.20}{5}$$

$$\sigma^2 = 13.84$$

Advantages and disadvantages of variance in geographical research

Despite the simplicity and accuracy in computation of the variance, its tendency to give more weight to extreme values by squaring them up remains a limiting factor.

(d) ***Standard deviation***

It is the value which shows how far the scores are spread from the normal or how the numbers are spread in a distribution. It is the most common index of variability. Standard deviation (SD) can be calculated for individual or grouped data. For ungrouped data, standard deviation can be calculated using the formula below:

$$S = \sqrt{\frac{\sum_{i=n}^{n}\left(x_i - \bar{x}\right)^2}{n}}$$

S = standard deviation from sample.
x = individual score
$\bar{x}$ = mean of sample
n = total number of observations in a sample

Procedures

(i) Calculate the mean of distribution;

(ii) Subtract the mean from each score to get deviations;

(iii) Square each of these deviations;

(iv) Add all the squares of these deviations;

(v) Divide the sum square deviations by the number of observations. The resulting quotient is called the variance; and

(vi) Calculate the square root of the variance to get the standard deviation(s).

Standard deviation for individual data (ungrouped data).

Example

The distribution of scores for class 'D' are 1, 2, 3, 4, 5, 6, 6, 7, 8, and 8. Determine the standard deviation.

Solution

Table 3.23: *Standard deviation on scores for class 'D'.*

Score (x_i)	$\bar{x}$	$x_i - \bar{x}$	$(x-\bar{x})^2$
8	5	3	9
6	5	1	1
3	5	–2	4
7	5	2	4
2	5	–3	9
8	5	3	9
1	5	– 4	16
4	5	–1	1
6	5	1	1
5	5	0	0
$\sum_{i=n}^{n} x_i = 50$			$\Sigma(x_i - \bar{x})^2 = 54$

$$\text{Mean } (\bar{x}) = \frac{\sum_{i=1}^{n} x_i}{n} = \frac{50}{10} = 5$$

From the given formula;

$$SD = \sqrt{\frac{\sum_{i=n}^{n}(x_i - \bar{x})^2}{n}}$$

$$= \sqrt{\frac{54}{10}}$$

$$= \sqrt{5.4}$$

$$= 2.32$$

Therefore, the standard deviation of the scores for class 'D' is 2.32.

Standard deviation for grouped data formula:

$$SD = \sqrt{\frac{\sum f(x_i - \bar{x})^2}{\sum f}} \quad \text{or}$$

$$SD = \sqrt{\frac{\Sigma fx^2}{\Sigma f} - \left(\frac{\Sigma fx}{\Sigma f}\right)^2}$$

Example:

Study Table 3.24 and find the standard deviation.

Table 3.24: *Geography subject scores for Form Five students in school Y*

Class interval	*f*
1 – 10	2
11 – 20	6
21 – 30	4
31 – 40	8
41 – 50	6
51 – 60	4
61 – 70	4
71 – 80	2
81 – 90	3
91 – 100	1

Solution

Table 3.25: *Standard deviation of Geography subject scores for Form Five students in school Y*

Scores	Class-mark (x)	f	fx	$\bar{x}$	$(x-\bar{x})$	$(x-\bar{x})^2$	$f(x-\bar{x})^2$
1 – 10	5.5	2	11	43.75	–38.25	1463.06	2926.12
11 – 20	15.5	6	93	43.75	–28.25	798.06	4788.36
21 – 30	25.5	4	102	43.75	–18.25	333.06	1332.24
31 – 40	35.5	8	284	43.75	–8.25	68.06	544.48
41 – 50	45.5	6	273	43.75	1.75	3.06	18.36
51 – 60	55.5	4	222	43.75	11.75	138.06	552.24
61 – 70	65.5	4	262	43.75	21.75	473.06	1892.24
71 – 80	75.5	2	151	43.75	31.75	1008.06	2016.12
81 – 90	85.5	3	256.5	43.75	41.75	1743.06	5229.18
91 – 100	95.5	1	95.5	43.75	51.75	2678.06	2678.06
Total		**$\sum f$=40**	**1750**				$\sum f(x-\bar{x})^2$ **= 21977.4**

$\sum f = 40$

$\sum fx = 1750$

$$\bar{x} = \frac{\sum fx}{\sum f} = \frac{1750}{40} = 43.75$$

$$\sum f(x-\bar{x})^2 = 21977.4$$

From the given formula:

$$SD = \sqrt{\frac{\sum f(x-\bar{x})^2}{\sum fx}}$$

$$= \sqrt{\frac{21977.4}{40}}$$

$$= \sqrt{549.44}$$

$$= 23.44$$

Therefore, the standard deviation of the scores for form five students in school Y is 23.44

Alternatively, compute the data in Table 3.24 for grouped data using the formula:

$$SD = \sqrt{\frac{\sum fx^2}{\sum f} - \left(\frac{\sum fx}{\sum f}\right)^2}$$

Solution

Table 3.26: *Summation of Geographical research scores for form five students in school Y*

Class Interval	f	x	x^2	fx^2	fx
1 – 10	2	5.5	30.25	60.5	11
11 – 20	6	15.5	240.25	1441.5	93
21 – 30	4	25.5	650.25	2601	102
31 – 40	8	35.5	1260. 25	10082	284
41 – 50	6	45.5	2070.25	12421.5	273
51 – 60	4	55.5	3080.25	12321	222
61 – 70	4	65.5	4290.25	17161	262
71 – 80	2	75.5	5700.25	11400.5	151
81 – 90	3	85.5	7310.25	21930.75	256.5
91 – 100	1	95.5	9120.25	9120.25	95.5
Total	**40**			**98540**	**1750**

$\sum f = 40$

$\sum fx^2 = 98540$

$\sum fx = 1750$

$$S = \sqrt{\frac{\sum fx^2}{\sum f} - \left(\frac{\sum fx}{\sum f}\right)^2} = \sqrt{\frac{98540}{40} - \left(\frac{1750}{40}\right)^2}$$

$$= \sqrt{2463.5 - (43.75)^2}$$

$$= \sqrt{2463.5 - 1914.0625}$$

$$= \sqrt{549.44}$$

$$= 23.44$$

Therefore, standard deviation of scores for form five students in School Y is 23.44.

Interpretation of standard deviation

The result of the calculated standard deviation is 23.44. SD can easily be interpreted when calculated and compared from two or more separate groups on the same subject studied, for example, SD for students' scores in Geography terminal examination. The greater the SD in one of the group say stream A compared to stream B will mean that the spread of the scores in stream A is greater compared to that of stream B . While dealing with standard deviation, it should be noted that if the calculated standard deviation is a large value, it means the scores are more spread. Thus, the greater the standard deviation, the greater the spread of the scores. The closer the scores are to the mean, the less spread they are, hence the smaller the standard deviation.

Strengths and weaknesses of standard deviation

Standard deviation is proved to have strengths as follows. Firstly, it is strictly defined and its value is always definite and based on all observations. Secondly, it uses the actual signs of observations; it is based on arithmetic mean; hence it has all the merits of arithmetic mean. Standard deviation is the most important and widely used measure of dispersion and gives possibility for further algebraic expression. Furthermore, it is minimally affected by the fluctuations of sampling, hence stable and creates a basis for measuring the coefficients of correlations and sampling.

Despite its strengths, standard deviation has some weaknesses such as being complex to understand and calculate; its tendency to give more weight to extreme values by squaring them up during computation and being an absolute measure of variability, hence not suitable for comparison purposes.

Activity 3.2

1. Take measurements of height for at least 10 members in your class and record them in a tabular form. Basing on the tabulated data, calculate the following:
   (a) Range
   (b) Mean deviation
   (c) Variance
   (d) Standard deviation
2. Using question 1(d) comment on the standard deviation obtained.

Exercise 3.2

1. Calculate the mean deviation from the given data in the following table.

x	7	13	15	19	21	23
Frequency	4	4	3	2	4	6

2. Study the table below indicating the scores for Geography subject in a mid-term test at school 'H' and then answer the questions that follow.

1-20	20-40	40-60	60-80	80-100
11	29	18	4	8

   Find
   (a) Mean deviation
   (b) Variance
   (c) Standard deviation

3. (a) Compare and contrast between mean and standard deviation.
   (b) Explain how variance can be obtained from:
   (i) Mean deviation
   (ii) Standard deviation

Presentation of geographical data

The art of turning unprocessed data into a visually appealing and easily interpreted format is known as *data presentation*. The intention of data presentation is to suit in explaining and substantiating a given studied phenomenon, clarity, the goal of the study, the scope of the study, sample size, type of data, and ease of use of results. Geographical data can be presented in a variety of methods, depending on the type of geographical information. Quantitative data can be presented using tables, diagrams, graphs/charts and maps. Qualitative data can be presented using tables, photographs, symbols, drawings, charts, diagrams, illustrations, and in textual form. Tables and graphs are among the effective communication techniques that interpret and convey geographical data and information. They enable readers to understand the content of geographical information, sustain their interest, and effectively present huge quantities of information.

The presentation of geographical data using graphs, diagrams, charts, and maps is commonly referred to as figures. In this context, it is the role of the geographer to choose appropriate research results presentation method that not only will help the readers understand the content, but also guide them by making meaningful interpretation of the presented research results.

Various methods can be used in presenting the data. There are three (3) major methods used in presenting geographical data, namely graphical charts, diagrammatic and map methods (Figure 3.5).

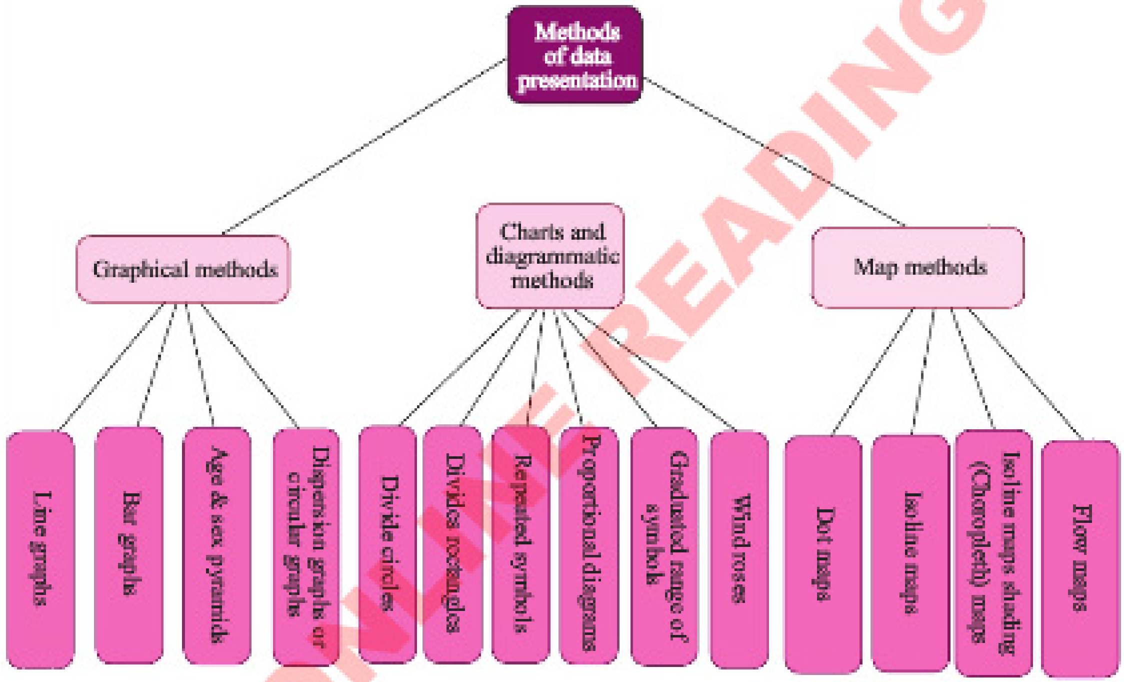


Figure 3.5: *The schematic presentation of geographical methods for data presentation*

Graphical method

This method is basically concerned with the relationship between quantities and does not stress the idea of location. Usually, the horizontal and vertical axes must appear as a basic and integral part of the drawing. These graphs are subdivided into line graphs, bar graphs, age and sex pyramids and dispersion graph or circular graphs.

Line graphs

Line graphs may be represented in four (4) ways: *Simple line graph, grouped line graph, compound line graph,* and *divergence line graph.*

Procedures for drawing line graphs

(i) The horizontal axis is normally used to represent the independent variable, for example time whether in hours, day, month's years or any other period of time;

(ii) The vertical axis is normally used to represent the dependent variable, for example quantities or values, sometimes as percentages;

(iii) Select the suitable scale by considering the highest value in the graph space;

If drawn on plain paper, it is preferable to draw two vertical axes, one at each end of the horizontal axis;

(iv) Do not indicate large numbers with long strings of roughs, for example 100,000 or 200,000, but write either at the top corner or along the side, the value of the units expressed in figures. For example tonnes; and

(v) There must be a title, a scale and a key.

Note: The procedures above are stated in a general way. However, they may slightly vary depending on the type of a line graph dealt with.

(a) Simple line graph

The simple line graphs are normally drawn to represent time series data related to the temperature, rainfall, population growth, birth rates and death rates. They are called simple because they have a single line. They are commonly used in data related to hospitals and meteorology. The data in Table 3.27 show the mean annual temperature that has been used to construct a simple line graph as shown in Figure 3.6.

Procedures for drawing a simple line graph in geographical data

(i) Identify the types of variables from your given data to horizontal scale (independent) and another in vertical scale (dependent);

(ii) Select the suitable scale by considering the highest value and the graph space;

(iii) Draw the horizontal and vertical lines according to the scale;

(iv) Plot the points and join them by straight line; and

(v) Write the title and the scale.

Example

Table 3.27: *Average temperature for Chololo village in Dodoma from 2010 to 2018*

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018
Temperature in °C	28.7	28.2	29	28.2	29.3	31.9	32.2	32.4	32.2

Source: Tanzania Meteorological Agency (2018)

Solution

Scale: V.S: 1 cm to 1 °C and H.S: 1 cm to 1 year

Figure 3.6: *Simple line graph showing trend of annual mean temperature in °C for Chololo village, in Dodoma (2010-2018)*

Advantages and disadvantages of simple line graphs in geographical research

The use of simple line graphs in geographical research has numerous advantages including simplicity in drawing and interpreting them. The continuous nature of the line or curve makes the technique suitable for displaying continuous data like temperature and rainfall variations over time. Simple line graph is also useful in displaying the relationship of two variables as shown in Figure 3.4 where the variation of temperature over years is shown. The line graph enables visualisation of variation of geographical data with rise or drop patterns. It is also,easy to read the exact values against the plotted point in straight line graph. Nonetheless, the simple line graph encounters some shortfalls such as the constrain of record limit which represents only one item on the graph. Another limitation of simple line graph is that it gives false impression of continuity of data even when there are periods the data is missing. The method is also criticised for giving unclear visual impression of actual quantities.

(b) Grouped line graphs

Grouped line graphs, also known as *comparative* or *multiple line graphs,* are graphs which present more than one item or series of data. Grouped line graphs display the relationship between sets of similar geographical data for two or more items. Note that the drawn line should not be uniform and on the other hand, presentation of five lines per graph is recommended. The data in Table 3.28 has been used to draw Figure 3.7.

Procedures

The following are procedures for constructing multiple line graphs

(i) Identify the variables from the given data;

(ii) Identify the item with highest value and use it to choose the scale;

(iii) Draw the horizontal and vertical lines;

(iv) Plot the points and join them with lines of different texture or colour for different dependent variables; and

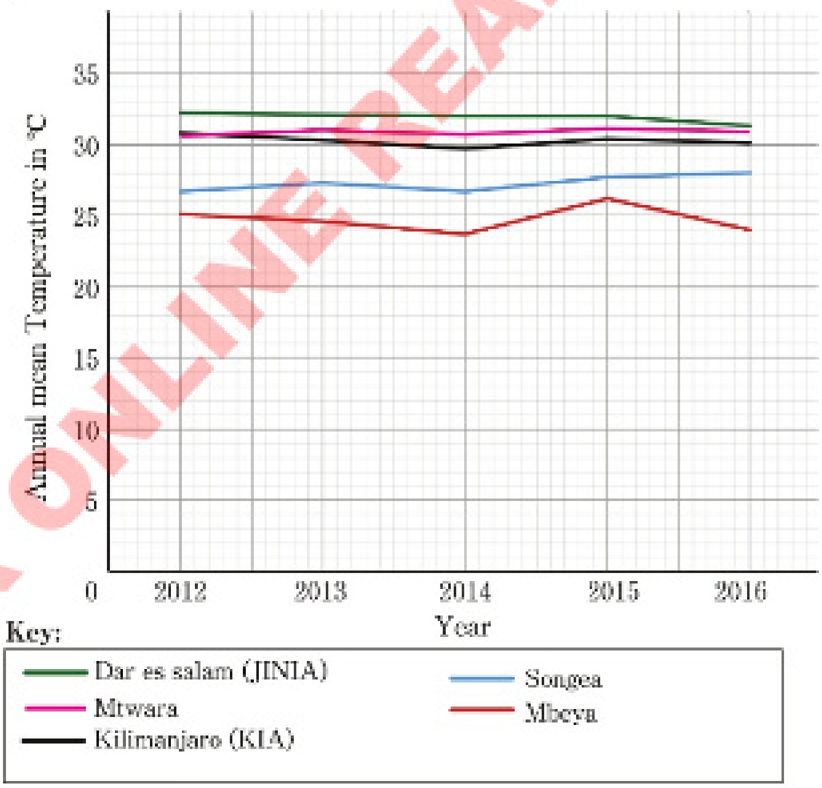
(v) Write the title, scale and show the key.

Table 3.28: *Annual mean temperatures from five meteorological stations in Tanzania from 2012 to 2016*

	Years				
Station	2012	2013	2014	2015	2016
Kilimanjaro (KIA)	30.8	30.3	29.7	30.4	30.1
Dar es Salaam (JNIA)	32.2	32.1	32.0	32.0	31.3
Mtwara	30.6	31.0	30.7	31.1	30.9
Songea	26.7	27.3	26.7	27.7	28.0
Mbeya	25.1	24.6	23.7	26.2	24.0

Source: *Tanzania Meteorological Agency (2018)*

Solution



Scale: V.S: 1 cm to 5 °C and H.S: 2 cm to 1 year

Figure 3.7: *Multiple line graph showing trends of annual mean temperature in °C from five meteorological stations in Tanzania from 2012 to 2016*

Advantages and disadvantages of multiple line graphs in geographical research

The use of group line graphs have a number of advantages, especially in making comparative analysis of data. They are detailed since they represent many items at once hence save time and space. They also have good visual impression especially if drawn correctly. The fluctuations of data can easily be noted. However, the line graphs face some limitations. They can be time consuming in both construction and interpretation. With crossing lines they may lead to confusion in interpretation. Sometimes they can be overcrowded in incidences of massive set of data and they can sometimes easily be confused with compound line graphs.

(c) Compound line graphs

Compound line graphs, also known as composite cumulative or divided line graphs, are drawn with several different components. On a compound line graph, the differences between the points on adjacent lines give the actual values. It is a good alternative to grouped line graph because the procedures for constructing are the same. The only difference is that instead of drawing lines in different colour or shade, they are all shown in bold form but the space between one line and the other is shaded differently. It is commonly suggested that values should be arranged in a certain order, with the highest values at the top and lower values at the bottom. Lines should not cross each other and data should be arranged in a cumulative manner. The data in Table 3.29 has been used to construct Figure 3.8.

Procedures

The following are procedures for drawing a compound line graph:

(i) Prepare a cumulative table by adding individual items to previous items as shown in Table 3.30;

(ii) Draw the x and y axes and choose a suitable horizontal and vertical scale;

(iii) Plot the dots for cumulative values of independent variables corresponding with the dependent variables from each item by rearranging from the largest to the smallest or vice versa. This rearrangement should be for the first year then in other years, items should follow the order of the first year;

(iv) Join the dots with portions of straight lines;

(v) The area occupied by each component presented on the graph, has to be coloured or shaded differently to give a clear distinction between the components;

(vi) Always start with the item with the highest value and end with item with the lowest value or vice versa;

(vii) Lines should not cross each other and data should be arranged in a cumulative manner; and

(viii) Write the title, scale and key.

Example

Table 3.29: *Electricity generation in Giga Watt per hour in Tanzania from 2011 to 2017*

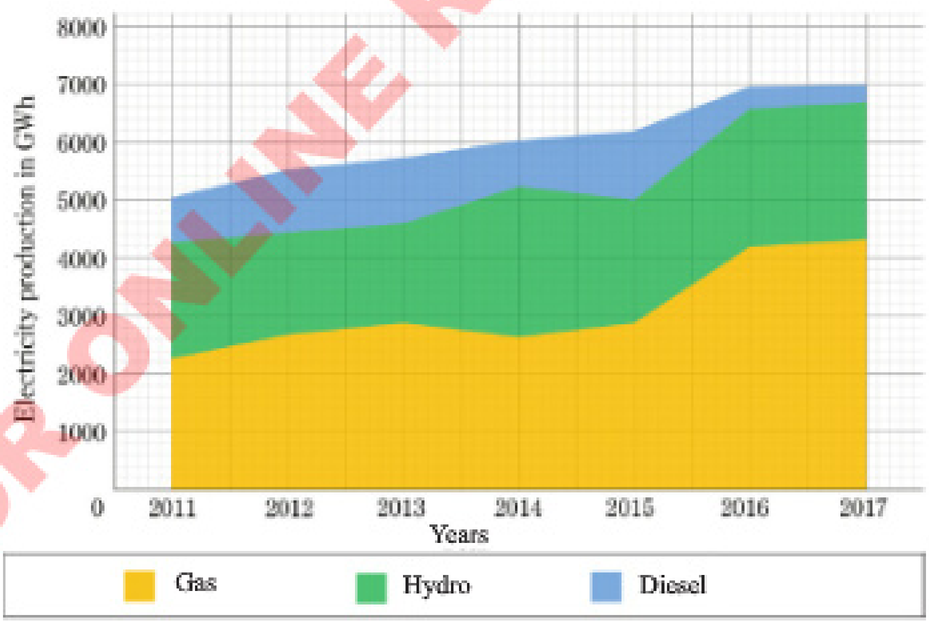
Year / Fuel source	2011	2012	2013	2014	2015	2016	2017
Hydro	1 992.6	1 769.9	1 721.3	2 613.5	2 124.4	2 382.1	2 369.1
Gas	2 265	2 664	2 872.2	2 624	2 873.8	4 196.4	4 322
Diesel	781.1	1 083.5	1 133.2	784.9	1 188.2	389.1	294.4

Source: Tanzania Electric Supply Company (2017)

Solution

Table 3.30: *Cumulative electricity generation in Giga watt per hour in Tanzania from 2011 – 2017*

Year / Fuel source	2011	2012	2013	2014	2015	2016	2017
Gas	2 265	2 664	2 872.2	2 624	2 873.8	4 196.4	4 322
Hydro	4 257.6	44 33.9	4 593.5	5 237.5	4 998.2	6 578.5	6 691.1
Diesel	5 038.7	5517.4	5 726.7	6 022.4	6 186.4	6 967.6	6 985.5



Scale :V.S : 1cm to 1000 GW/h and H.S: 2cm to 1 year

Figure 3.8: *Compound line graph for electricity generation in Giga watt per hour in Tanzania from 2011 to 2017*

Advantages and disadvantages of compound line graphs in geographical research

The compound line graphs are beneficial in many ways, specifically in their ability to display multiple values for overall conclusion and suggestion; giving a visual impression that encourages understanding to interpreters; and combining several graphs at once. However, the method is associated with some drawbacks including calculations that may be difficult and time consuming. The interpretation of data is also likely to be complicated. Cumulative data also hides the reality of original data.

(d) Divergent line graphs

These are used to show fluctuations in value in terms of 'positives' or 'negatives' also known as 'profits or losses', 'gains or losses' and 'increases or decreases'. Such fluctuations are common in imports and exports, population trends and production of goods and commodities. The graph can also address the increase and decrease pattern of temperature and rainfall trends. As such, the graph can be used by climatologists, meteorologists and geographers in drawing insights on the extent of extreme weather events, climate change and variability as well as their effects on the environment and human welfare. Data in Table 3.31 has been used to draw Figure 3.9.

Procedures

The following are the procedures for drawing a divergent line graph:

(i) Find the sum of the values of observations in the set of data as shown in Table 3.25(b);

(ii) Calculate the mean by dividing the sum in (i) by the number of observation as:

$$\bar{x} = \sum_{i=1}^{N} x_i = \frac{272.1}{9} = 30.2;$$

(iii) Subtract the mean from each data/value as shown in Table 3.25(b);

(iv) Plot the divergences (positive and negatives) on a graph with positive on the upper part of mean (zero) line and negatives below it by putting dots as shown in Figure 3.7; (zero) line must be bolded; and

(v) Finally, join the dots sequentially as shown in Figure 3.7. The zero line represents the mean; one side of the (zero) line should indicate the mean.

Example

Table 3.31: *Average temperature for Chololo village in Dodoma from 2010 to 2018*

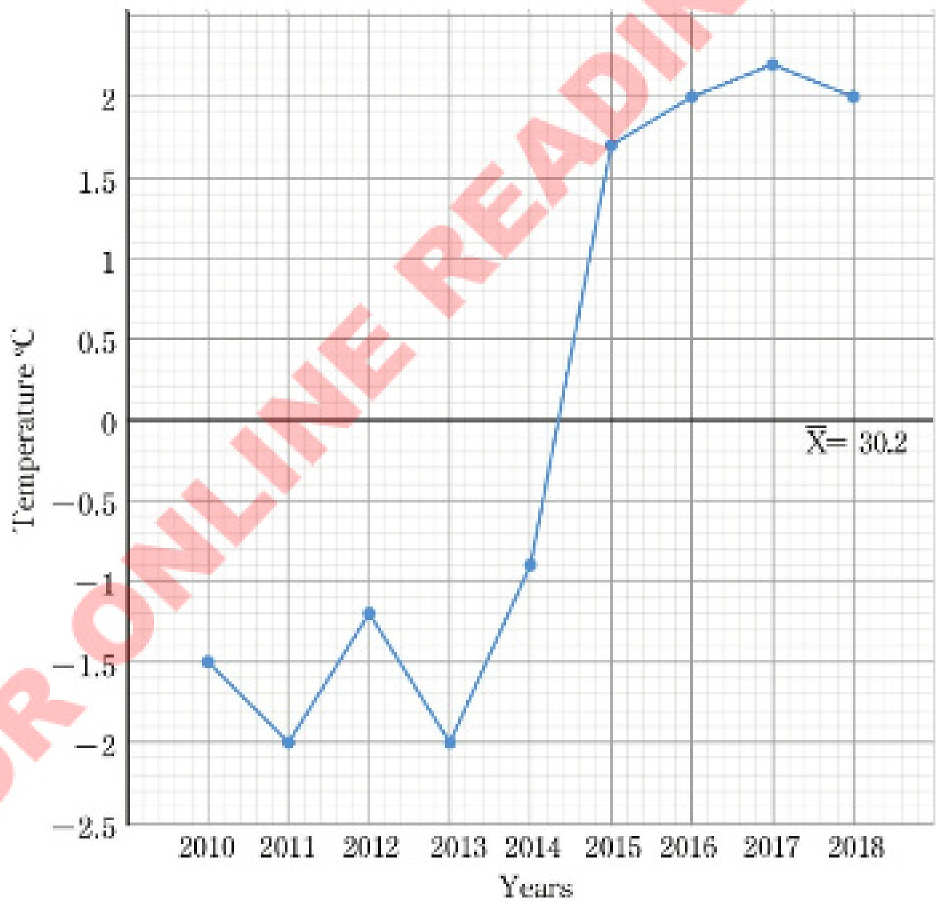
Year	2010	2011	2012	2013	2014	2015	2016	2017	2018
Temperature in °C	28.7	28.2	29	28.2	29.3	31.9	32.2	32.4	32.2

Source: *Tanzania Meteorological Agency (2018)*

Solution

Table 3.32: *Deviation of average temperature for Chololo village, in Dodoma from 2010 to 2018*

Year	Temperature (x_i)	$\bar{x}$	$x_i - \bar{x}$
2010	28.7	30.2	− 1.5
2011	28.2	30.2	− 2
2012	29	30.2	− 1.2
2013	28.2	30.2	− 2
2014	29.3	30.2	− 0.9
2015	31.9	30.2	1.7
2016	32.2	30.2	2
2017	32.4	30.2	2.2
2018	32.2	30.2	2
	$\sum_{i=1}^{n} x_i = 272.1$		



Scale: V.S: 1 cm to 0.5 °C and H.S: 1 cm to 1 year

Figure 3.9: *The divergent line graph for the average temperature for Chololo village, in Dodoma from 2010 to 2018*

Advantages and disadvantages of divergent line graphs in geographical research

Some of the major advantages of the divergent line graphs include the fact that fluctuation from the mean can be noted easily. Moreover, the graphs are simple to read and interpret, and simple in presenting values. They easily compare the items, hence facilitate sound conclusion. Other benefits include their merits in showing the positives (profits) and negatives (losses) and reasonably easy to construct.

Despite such advantages, divergent line graphs have the following limitations: inability to show the sums under the study; instead, they display only the positive and negative divergences. Positive and negative values may mislead the interpretation if not skilled. They can be difficult to interpret, particularly to some individuals who have limited geographical research skills. Normally, they are only restricted to one item per graph.

Bar graphs

A bar graph, also known as a *column graph*, refers to an x-y graph showing the tendencies of various geographical phenomena notably rainfall, population, export and import, and other quantities like goods. Each tendency is shown by a column or bar whose length or height represents its value along the y-axis. The purpose of the graph is to show numerical facts in visual form so that they can be understood quickly, easily and clearly. Bar graphs are appropriate when there is a need to present trends or comparison. In showing comparison, the graphs may consist of two or more parallel verticals (or horizontal) bars or rectangles.

a) Simple bar graphs

Simple bar graphs consist of parallel, usually vertical bars or rectangles with length proportional to the frequency with which specified quantities occur in a set of data. It can be defined as quantitative comparison by rectangles with lengths proportional to the measure of the data or things being compared. Data in Table 3.33 has been used to draw Figure 3.9:

Procedures

The following are procedures for drawing a simple bar graph:

(i) From the given data, identify the types of variables;

(ii) Draw horizontal and vertical line and construct bars vertically above the horizontal lines;

(iii) Along the horizontal axis, choose the uniform width of bars and uniform gap between the bars and write the names of the data items whose values are to be marked;

(iv) Along the vertical axis, choose a suitable scale in order to determine the heights of the bars for the given values (Frequency is taken along y-axis);

(v) Calculate the heights of each bar according to the scale chosen and draw the bars;

(vi) Shade the bars equally; and

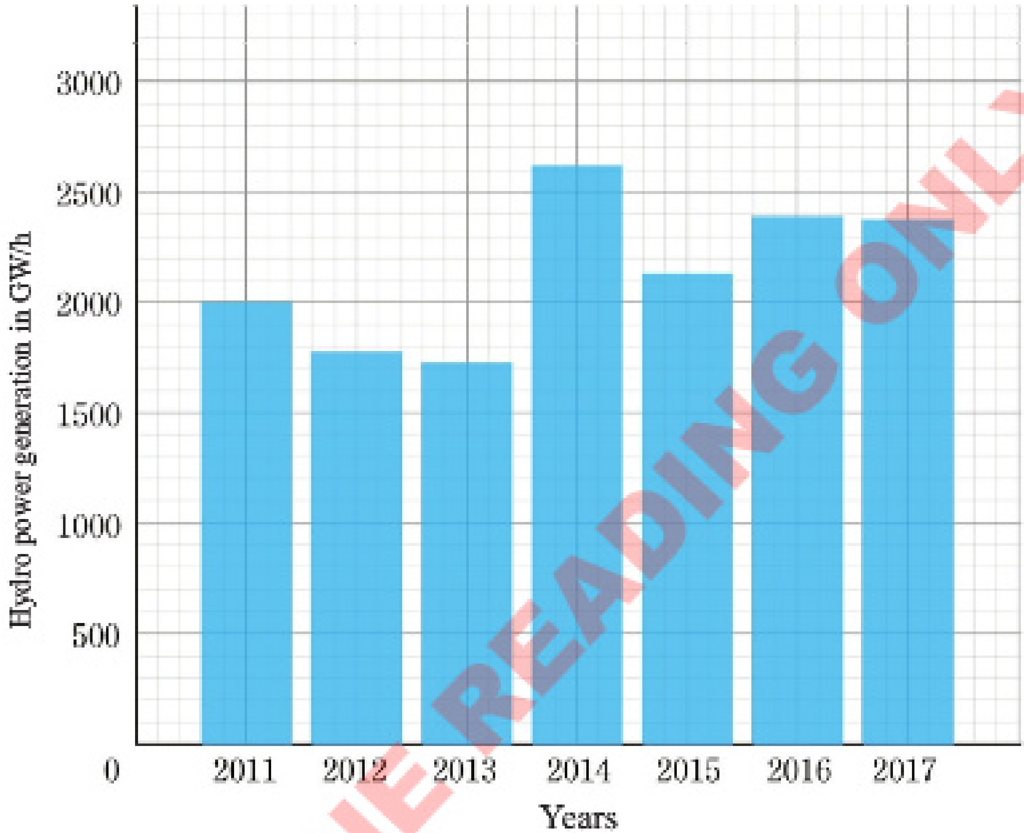
(vii) Write the title and the key.

Table 3.33: *Hydroelectric power generation in Giga Watt per hour in Tanzania from 2011 to 2017*

Year	2011	2012	2013	2014	2015	2016	2017
Hydro	1992.6	1 769.9	1 721.3	2 613.5	2 124.4	2 382.1	2 369.1

Source: TANESCO (2017)

Solution



Scale: V. S 1cm to 500 GWh and H.S: 1cm to 1 year

Figure 3.9: *Simple bar graph for hydroelectric power generation in GWh in Tanzania from 2011 to 2017*

Other things to bear in mind when drawing simple bar graphs include:

(i) A vertical bar may occupy the space (either completely or partially) between two vertical lines;

(ii) All bars must start at zero. Bar graphs drawn for the purposes of comparison must be drawn on the same scale; and

(iii) The width of the bar is a matter of choice, avoid bars that are too thick or too thin. The value of each bar can be assessed easily if a space or gap is left between each bar.

Advantages and disadvantages of simple bar graphs in geographical research

The simple bar graphs are beneficial because they are easy to draw and interpret; they can be used in conjunction with line graphs. Again, their rise and fall patterns at a given time can be easily visualised. Simple graphs also present tangible quantities better than line graphs.

Simple graphs also have some limitations. The major limitations include inability to present many items and in cases of scale exaggeration the graph may be distorted. Furthermore, they consume more space in cases of huge data.

b) Grouped bar graph

Grouped bar graph, also known as *comparative* or *multiple bar graph*, is where two or more simple bars are grouped side by side on the same vertical scale for the sake of comparison. It is a graph that uses rectangular bars to represent different values for showing comparisons among categories such as the amount of rainfall in different months of a year, or the average salary in different states. Grouped bar graphs are commonly drawn vertically, though they can also be depicted horizontally.

The data in Table 3.34 has been used to draw Figure 3.11.

Procedures

The following are procedures for drawing a group bar graph:

(i) Draw and label the vertical and horizontal axes;

(ii) Choose a scale that suits the data;

(iii) To give an impression of totality, bars are usually drawn touching each other, that is, without a gap between them, but attention should be paid to individual components by leaving a small space between the bars. Also, groups of bars must be separated from each other with a similar space or gap;

(iv) It is a custom to draw the bars of each group in ascending or descending order for comparison purposes;

(v) All bars must be of the same width and drawn at right angles to the axis; and

(vi) Write the title, scale and the key.

Example

Table 3.34: *Electricity generation in Giga Watt per hour in Tanzania from 2011 to 2017*

	2011	2012	2013	2014	2015	2016	2017
Hydro-electric power	1992.6	1769.9	1721.3	2613.5	2124.4	2382.1	2369.1
Gas	2265	2664	2872.2	2624	2873.8	4196.4	4322
Diesel	781.1	1083.5	1133.2	784.9	1188.2	389.1	294.4

Source: *Tanzania Electric Supply Company (2017)*

Scale: V. S: 1 cm to 500 GWh and H.S: 1.5 cm to 1 year

Figure 3.11: *Grouped bar graph for electricity generation in Giga Watt per hour in Tanzania from 2011 to 2017*

Advantages and disadvantages of grouped bar graphs in geographical research

The grouped bar graph is useful in the field of geography in many ways. Firstly, it enables a reader to get a good visual impression about the totality and individuality of the studied item(s). Secondly, it enables easy comparison of the investigated components interpretation is also relatively simple and easy. The bars may be drawn within one another, particularly for the overlapping bars. Additionally, many items can be presented together in the same graph hence saving space. Despite the given merits, grouped bar graph has limitations such as difficulties in comparing some of the items with varying years which cannot be expressed. Composing the scale is also challenging. Apart from that, grouped bar graphs are time consuming in constructing and difficult to compare the sum in each year when there are many groups of bars.

(c) Compound bar graphs

Compound bar graphs refers to graphs which combine two or more types of information in one graph. They can also compare different quantities. A compound bar graph is a type of a bar chart where columns can be split into sections to show breakdown of data. It is drawn by subdividing one bar into component parts. The total length of the bar represents the total value of the entire component in which parts are shown in such division. Data in Table 3.35 has been used to draw Figure 3.12.

Procedures

(i) Identify the types of variables;

(ii) Find the item with the highest total;

(iii) Prepare the cumulative table and enter the values cumulatively starting with the highest or the smallest to largest item. This rearrangement should be for the first year and the following years should follow the established order;

(iv) Use the highest total among the total in the table to select a suitable vertical scale. For the case of horizontal scale, the number of items of independent variables should be considered;

(v) Draw the vertical and horizontal lines;

(vi) Draw bars vertically above the horizontal line, the height of each depends on its total in the cumulative table;

(vii) Divide and shade bars accordingly; and

(viii) Write the title, scale and the key.

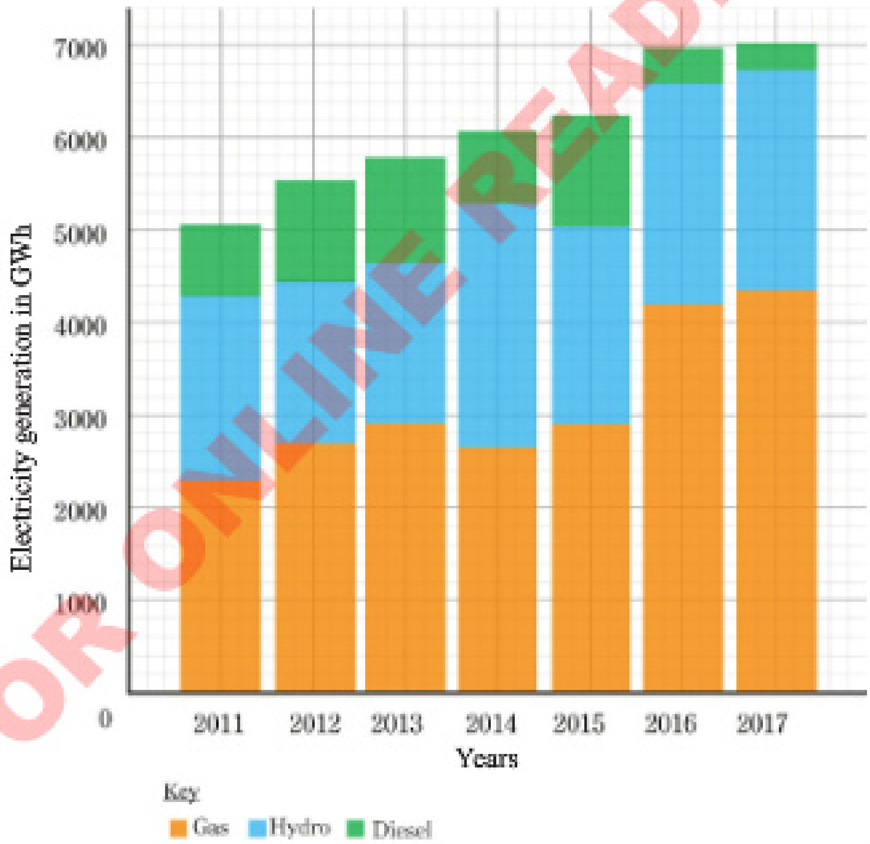
Example

Table 3.35: *Electricity generation in Giga Watt per hour in Tanzania from 2011 to 2017*

	2011	2012	2013	2014	2015	2016	2017
Hydro	1992.6	1769.9	1721.3	2613.5	2124.4	2382.1	2369.1
Gas	2265	2664	2872.2	2624	2873.8	4196.4	4322
Diesel	781.1	1083.5	1133.2	784.9	1188.2	389.1	294.4

Source: *Tanzania Electric Supply Company (2017)*

Solution



Scale: V.S: 1cm to 1000 GWh and H.S: 1cm to 1 Year

Figure 3.12: *Compound bar graph for electricity generation in Giga watt per hour in Tanzania from 2011 to 2017*

Advantages and disadvantages of compound bar graphs in geographical research

A compound bar graph is easy to construct and make comparison. The associated colouring and shading of the graphs improves visual impression and simplifies interpretation. A compound bar graph allows expressing more than one quantities within the chart. However, compound bar graphs have some drawbacks including difficulties in assessing the value of one component or tracing its fluctuation over a period of time. The graphs involve cumulative data which demand some calculations, which are time consuming. Furthermore, compound bar graphs have a limitation in presenting many components due to limited space of accommodating long graphs. It is difficult to compose scale if the range of values is very large.

(d) Divergent bar graphs

In this type of graphs, data spread is both positive and negative and it is displayed divergently. These can be constructed on either the x or y axis. Divergent bar graphs are used when one set of data is provided for part of the period under consideration and then this dataset is split into separate components for another part of the period. Data in Table 3.36 has been used to draw Figure 3.13. Note that the Tanzania and Zambia Railway Authority (TAZARA) is excluded.

Procedures

(i) Find the sum of the number of observations in the set of data as shown in Table 3.28(b);

(ii) Calculate the mean as

$$\bar{x} = \sum_{i=1}^{n} x_i = \frac{1589.4}{6} = 264.9;$$

(iii) Subtract the mean from each data or value given to get deviation;

(iv) Select suitable vertical and horizontal scales;

(v) Plot the divergences (positives and negatives) on a graph with positives on the upper part of mean (zero) line and negatives below it; zero line must be bold;

(vi) Draw bars up and down the line of average and shade them equally; and

(vii) Write the title, and scale.

Note: The zero line must be clearly indicated usually by thickening. As the bar, the horizontal scale is in fact best written at the bottom and top of the graph. The vertical axis must be scaled both above and below the zero line, the upper part for positive and the lower for negative values.

Example

Table 3.36: *Passengers transported in thousand ('000) by the Tanzania Railways from 2010 to 2015*

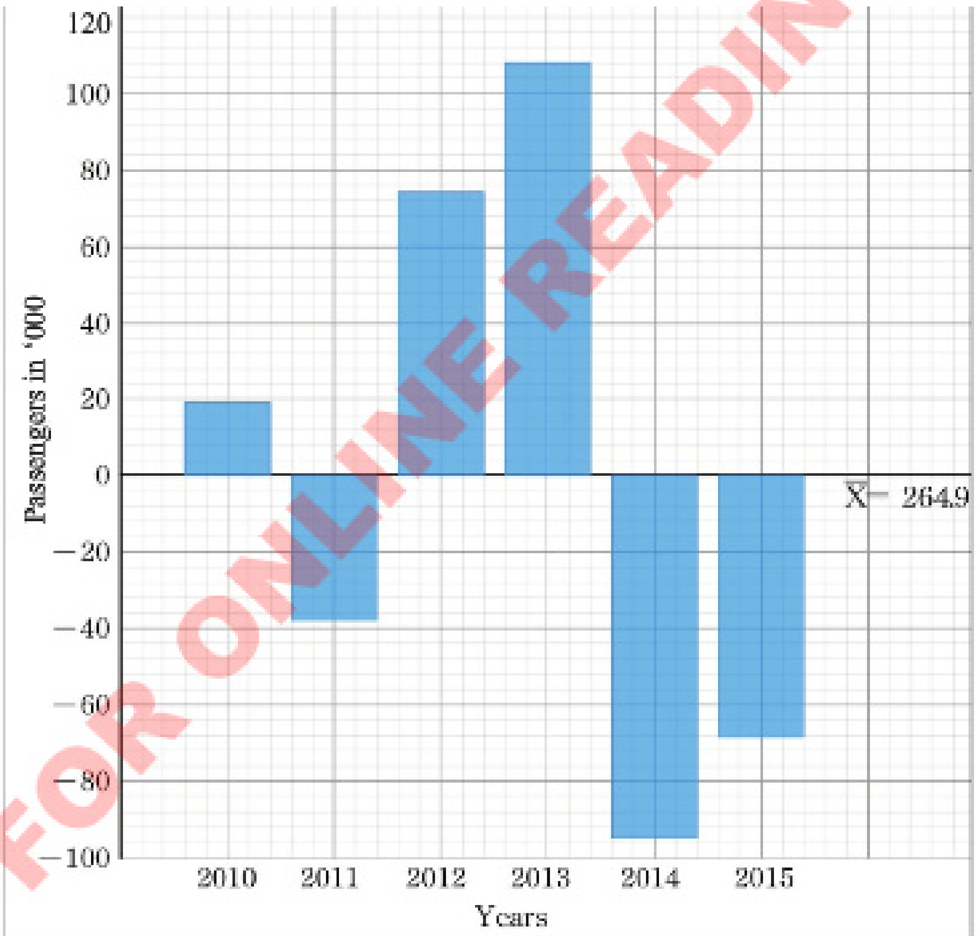
Year	2010	2011	2012	2013	2014	2015
Passengers in thousand	284	227	339	373	170	196.4

Source: Ministry of Works, Transport and Communication (2015)

Solution:

Table 3.37): *Deviation of passengers transported in thousand ('000) by the Tanzania Railways from 2010 to 2015*

Year	Total number of passengers in '000 thousand (x_i)	$\bar{x}$	$x_i - \bar{x}$
2010	284	264.9	19.1
2011	227	264.9	– 37.9
2012	339	264.9	74.1
2013	373	264.9	108.1
2014	170	264.9	– 94.9
2015	196.4	264.9	– 68.5
	$\sum_{i=1}^{n} x_i = 1589.4$		



Scale: V.S: 1 cm to 20 passengers H.S: 1 cm to 1 year

Figure 3.13: *The divergent bar graph for passengers transported in thousand ('000) by the Tanzania Railways from 2010 to 2015*

Advantages and disadvantages of divergent bar graphs in geographical research

Divergent bar graphs have advantages including the fluctuation in values which are helpful in detecting a problem in general terms as shown in Figure 3.13. They are also important in comparing the negatives and positives of the phenomenon under observation. They further enable easy deduction of the profit (loss or rise) or loss (failure or rise) of the phenomenon observed. Divergent bar graphs are simple to construct, read and interpret. However, the graphs have some limitations like being time consuming as their construction involves many steps. They demand skills in mathematics and they are confined to analysis of only one variable. Also, they do not present actual data, but present data showing variations from the mean.

A combined line and bar graph

Sometimes a simple line and a bar graph may be combined in the same graph to show more often climate data such as temperature and rainfall. This type of graph is termed as a climograph.

The hypothetical data in Table 3.38 has been used to draw Figure 3.14.

Procedures

(i) Select variables to be presented by line and bar graphs;

(ii) In this case, rainfall will be in bars and temperature is plotted in the line which is above the bars;

(iii) Similar procedures for the drawing of simple line and bar graphs need to be used to draw a combined line and bar graph;

(iv) Choose a different scale for rainfall and temperature; and

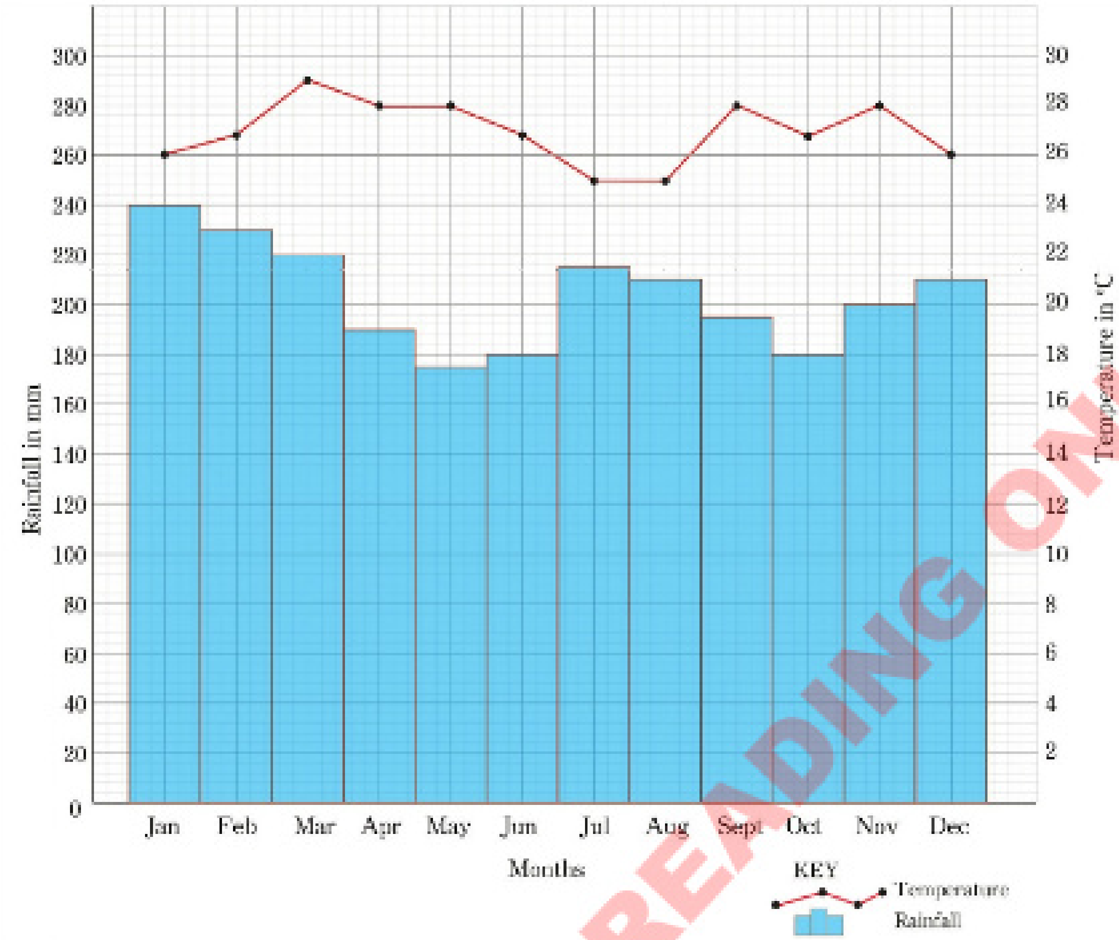
(v) Write the title, key and scale.

Example

Table 3.38: *Temperature and rainfall recorded at station X*

Months	J	F	M	A	M	J	J	A	S	O	N	D
Temperature (°C)	26	27	29	28	28	27	25	25	28	27	28	26
Rainfall (mm)	240	230	220	190	175	180	215	210	195	180	200	210

Solution:



Scale: HS: 1 cm to 1 month, VS for Temp: 1 cm to 2 °C, V.S for Rainfall: 1 cm to 20 mm

Figure 3.14: *A combined line and bar graph (Climography) for station X*

Age - sex graphs

A population pyramid, also known as *age and sex pyramid, population structure or age and sex structure* refers to the geographical representation of age structures or distributions of population according to age groups. The graph is commonly used by demographers. The graphs can be constructed to represent composition of a population in a region, country or worldwide. Age-sex graphs are not only restricted to showing composition of age group but also extend to sex of the population composition. Normally, age groups appear along the vertical (y-axis) while sex is placed on the horizontal line (x-axis). Basically, female is located on the right side and male on the left side shown in absolute number or percentage in successive age groups (Figure 3.15). Pyramids are useful in presenting the population which depends on the birth rates, death rates and migration. These graphs are relevant in summarising the age and sex data collected from census survey. Through these types of graphs, the country can deduce various insights and information useful for decision-making such as distribution of social services and intervention measures as well as identifying the working group and the dependant, with regard to varying social groups. Often the population for comparison purposes is constructed on the same scale and should depict the same age groups. Bars should be of the same height. The structure of the pyramids is dynamic depending on the changes of population structure. The demographics change from pyramid and finally to barrel which end the point of the population pyramids.

Types of population pyramids

The population pyramids are of varying shapes. Although different countries can have unique pyramids, still the pyramids in the same countries can take different shapes over different periods of time. Normally, this is influenced by spatial and temporal variations over time. Changes in the number of the population whether by age or sex are among the quantitative variables of interest in geographical research in describing the population. The graphical representation of the population pyramids ultimately relies on age and sex structures of a given population. Such shapes may take the form of a triangular pyramid, and have a columnar or rectangular profile (with vertical sides rather than sloped sides), or have an irregular profile. Demographers identify three types of pyramids, namely: expansive or rapid growth, stationary or slow growth and constrictive or contractive or negative growth pyramids.

Expansive pyramid: This is also known as *rapid growth pyramid*. It has a broad base with successive decline in the share of population of higher age groups. The pyramid represents relatively high fertility and mortality rates; low life expectancy; higher population growth rates; and low share of old age persons. The pyramids portray the expansion of population as the size of each cohort gets larger than the size of the same in previous time. Expansive age pyramids are common for developing countries, mainly in Africa and Asia. Figure 3.15 which shows the population distribution in Tanzania basing on the census of 2012 is a typical representation of an expansive pyramid. As such, distribution varies with time and space; the slight or complete change in the structure of the population in the country for the subsequent census will not be a surprise. In drawing population pyramids, you should consider the following.

(i) The age groups are usually based on quinquennial (5 years) periods (0 - 4, 5 - 9, 10 - 14) with the youngest age group forming the base of the graph;

(ii) In calculating percentage, two methods are possible: either the individual male or female population or each group may be calculated as percentages of the total population; and

(iii) It should be noted that the procedures for constructing the population pyramids are common across all types of pyramids. The shapes of resultant pyramids are also the result of a population composition at a particular time and space.

Procedures

The following are the procedures for drawing are age and sex graph:

(i) Identify types of variables and suggest suitable scales. For vertical scale, consider the number of age groups, and for the horizontal scale, consider the highest value or percent;

(ii) Draw two vertically standing lines of not more than 2 cm apart. Note that, 2 cm wide is suitable at the centre of the graph paper;

(iii) From the bottom of the lines, draw two horizontal lines away from each other to represent the sex, male on the left and female on the right side;

(iv) The bars are drawn horizontally and their length corresponds to the size of the age groups. It is in fact a comparative bar graph drawn horizontally; and

(v) Shade the bars, write the title and indicate the scale.

Example

Study the data provided in Table 3.39, then construct age and sex graph by using absolute value as shown in Figure 3.15.

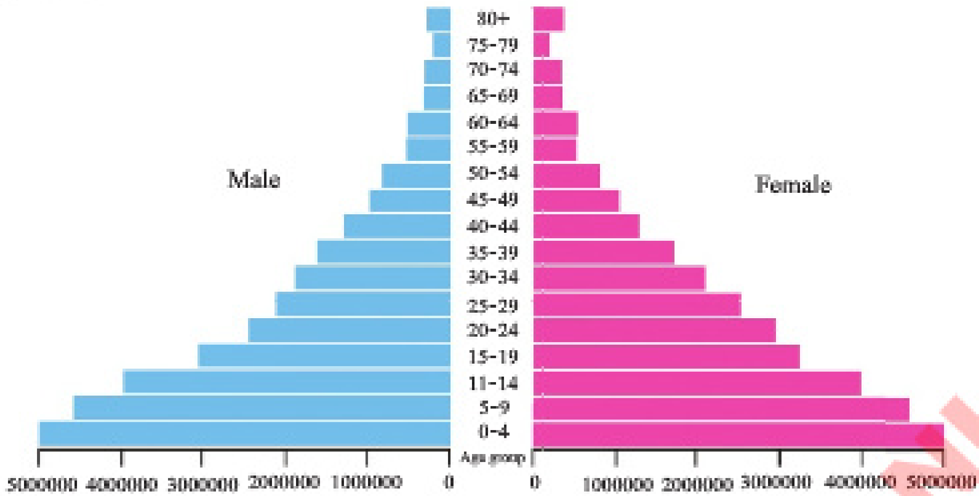
Table 3.39 : *Population distribution by age and sex based on the 2012 census survey*

Age group	Male	Female
0 – 4	3,535,673	3,534,222
5 – 9	3,242 111	3,233,253
10 – 14	2 809 113	2,816,735
15 – 19	2 171 355	2,295,319
20 – 24	1 737 849	2,093,249
25 – 29	1 503 841	1,789,025
30 – 34	1 342 110	1,485,372
35 – 39	1 149 418	1,219,682
40 – 44	916 020	924,316
45 – 49	694 318	759,147
50 – 54	5 87 555	585,004
55 – 59	3 9 627	371,783
60 – 64	368 814	380,318
65 – 69	232 811	248,460
70 – 74	220 651	245,426
75 – 79	149 974	145,122
80+	2 060 73	259,608

Source: *Tanzania population census Survey (2012)*

(a) By the use of absolute value

Solution



Scale: H.S: 1 cm to 100 000 and V.S: 0.5 cm to 1 bar

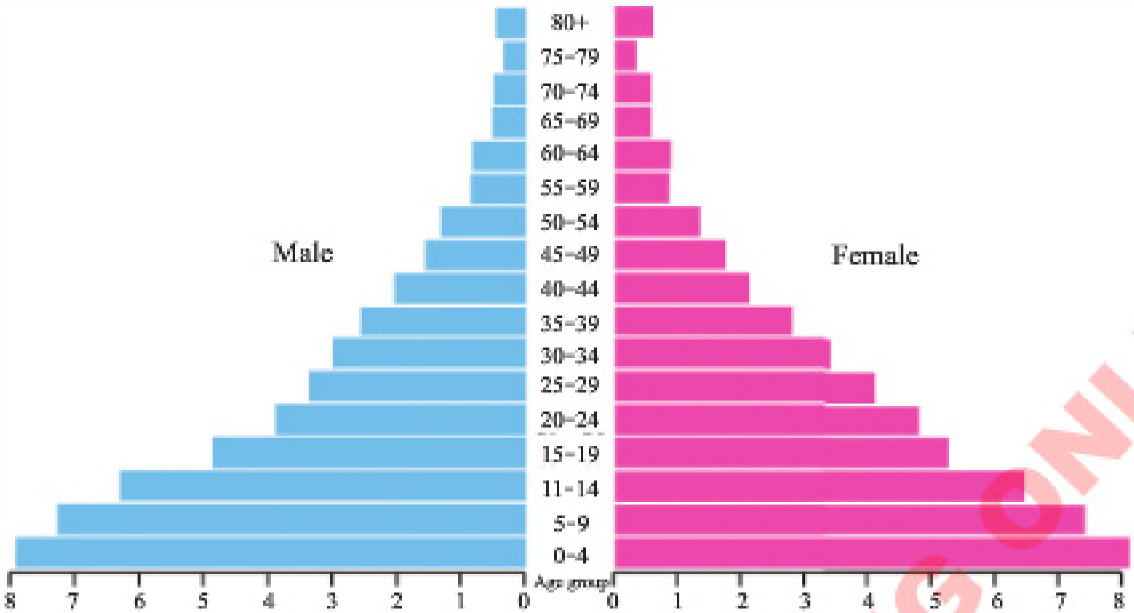
Figure 3.15: *Population pyramid of Tanzania mainland based on 2012 census survey*

Population pyramids can also be constructed using percentage values. To construct population pyramids using data in Table 3.39, first, calculate the total population for each age group as shown in Table 3.40. Then, calculate the male and female percentage for each age group as shown in Table 3.40. Finally follow the same procedures in (i) to (v) above to construct population pyramids as shown in Figure 3.16.

Table 3.40: *By the use of percentage value*

Age group	Male	Female	Total	%Male	%Female
0 – 4	3 535 673	3 534 222	7 069 895	8.103	8.100
5 – 9	3 24 2 111	3 233 253	6 475 364	7.430	7.410
10 – 14	2 809 113	2 816 735	5 625 848	6.438	6.455
15 – 19	2 171 355	2 295 319	4 466 674	4.976	5.260
20 – 24	1 737 849	2 093 249	3 831 098	3.983	4.797
25 – 29	1 503 841	1 789 025	3 292 866	3.447	4.100
30 – 34	1 342 110	1 485 372	2 827 482	3.076	3.404
35 – 39	1 149 418	1 219 682	2 369 100	2.634	2.795
40 – 44	916 020	924 316	1 840 336	2.099	2.118
45 – 49	694 318	759 147	1 453 465	1.591	1.740
50 – 54	587 555	585 004	1 172559	1.347	1.341
55 – 59	379 627	371 783	7 51 410	0.870	0.852
60 – 64	368 814	380 318	749 132	0.845	0.872
65 – 69	232 811	248 460	481 271	0.534	0.569
70 – 74	220 651	245 426	466 077	0.506	0.562
75 – 79	149 974	145 122	295 096	0.344	0.333
80+	2060 73	259 608	465 681	0.472	0.595
Total	21 247 313	22 386 041	43 633 354	50	50

(b) By the use of percentage value



Scale: H.S: 1 cm to 1% and V.S: 0.5 cm to 1 bar

Figure 3.16: *Age and sex pyramid of Tanzania mainland based on the 2012 census survey*

Stationary pyramid: This is also known as a *slow growth curve*. Stationary pyramids are the pyramids describing a constant share of population in different age groups over a period of time. They display a situation with low fertility and mortality rates and high life expectancy. They depict a slow population growth or stable population. The stationary or near stationary population pyramid displays some what equal share of juvenile and adult age groups as shown in Figure 3.17.

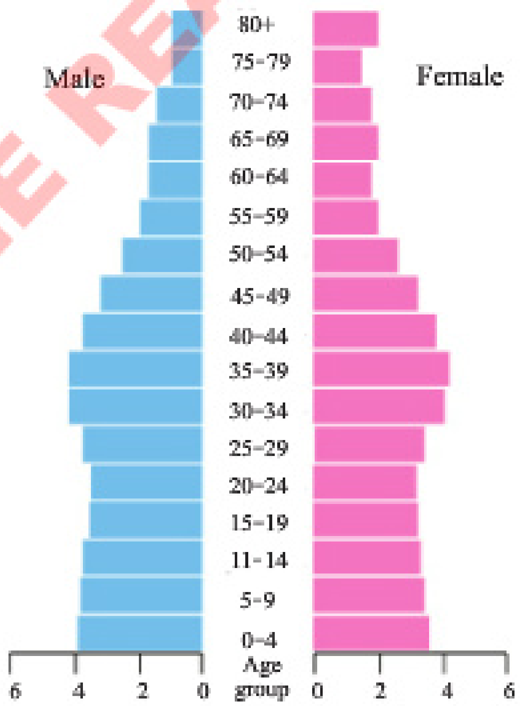


Figure 3.17: *Stationary pyramid*

Constrictive pyramid: This is also known as a contractive or negative growth pyramid. It is a pyramid with a narrow base. It displays a low fertility and mortality rate, where life expectancy and ageing of the population are high. The pyramids are typically common in developed countries where they have a high level of literacy, access to birth control measures and quality health care associated with improved medical facilities (Figure 3.18).

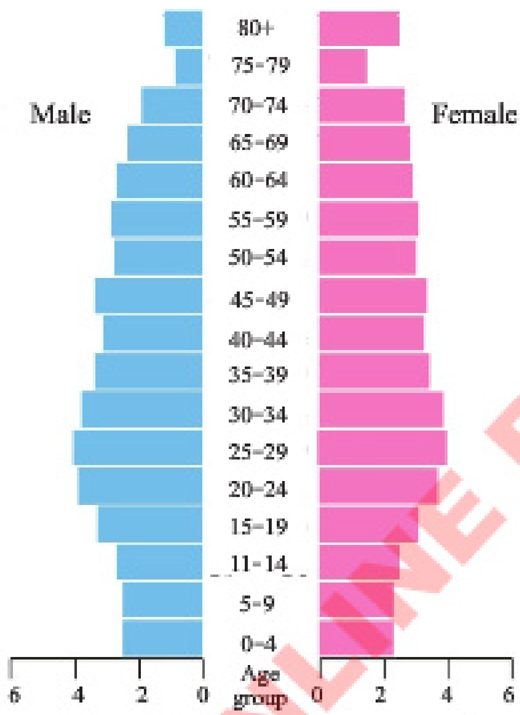


Figure 3.18: *Constrictive pyramid*

Advantages and disadvantages of age and sex graphs or population pyramids in geographical research

The age and sex graphs are beneficial in many ways. Firstly, they clearly show the comparison between males and females. They give a clear picture of summary of population composition that is visually attractive. On one hand, they define economic status of a given country, its fertility and mortality rates and life expectancy. On the other hand, they show the trend of population change in terms of birth and death. The limitations of the population pyramids are time consuming caused by tedious steps of calculations involved in tabulating the pyramid and determining the scale.

A compounded population pyramid

This is also referred to as a superimposed population pyramid. It is a population pyramid which comprises different population categories superimposed in one bar.

Procedures

(i) Identify the types of variables for this case age, sex and employment variable and suggest suitable scales;

(ii) Draw two vertically standing lines of not more than two (2 cm) apart;

(iii) The bars of sex and employment are drawn horizontally and their lengths correspond the size of the age groups. The bars of employment are also drawn horizontally and their corresponding size are superimposed on the respective age; and

(iv) Shade the bars, write the title and indicate the scale.

Example

Study the data provided in Table 3.41, then, using absolute values, draw a comparative population structure to represent the following data for country x.

Table 3.41: *Data for population structure and employment for country x*

Age group	Total population		Population in employment	
	Male	Female	Male	Female
20 – 24	85,000	100,000	60,000	50,000
25 – 29	70,000	80,000	50,000	30,000
30 – 34	60,000	74,000	52,000	52,000
35 – 39	52,000	62,000	48,000	30,000
40 – 44	44,000	48,000	30,000	20,000
45 – 49	30,000	32,000	25,000	25,000
50 – 54	23,000	28,000	15,000	16,000
55 – 59	15,000	16,000	8,000	5,000
60 – 64	10,000	12,000	5,000	8,000
65 – 69	5,000	8,000	2,000	2,000

Solution:

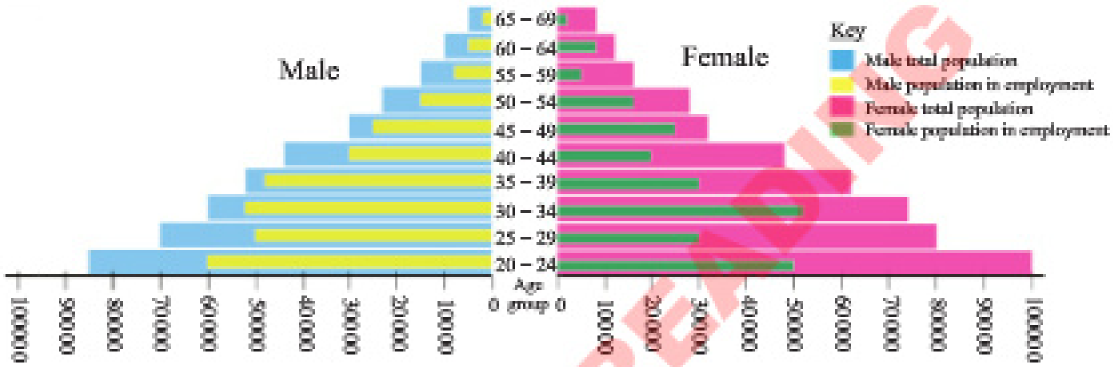


Figure 3.19: *Compounded population structure of country x*

Advantages and disadvantages of compounded population pyramids in geographical research

This type of pyramid is useful to show comparison between males and females in different categories, for example, distribution of males and females in employment and education. It also shows characteristics of the population that is either from developed or developing nations. Population pyramids gives a clear visual impression, although they are tedious to construct.

Circular graph

A circular graph is also known as *dispersion, clock* or *polar graph* due to its resemblance to the face of a clock or lines of longitude radiating from the pole. The analogy between the twelve months of the year and the twelve hours of the clock face adds attraction to the use of this type of graph. It is mostly used to show the seasonal calendar in a year for farmers.

Procedures

The following are the procedures for drawing a circular graph:

(i) Identify the types of variables and select a suitable scale;

(ii) Draw seven concentric circles, the smallest at the centre should be not more than 2 cm in diameter. This, however, it depends on the size of the paper. Distance from one circle to another should be 1cm;

(iii) Draw 12 radii of 30° apart, starting from 12 o'clock radius clockwise. The 12 radii stand for months of the year, named clockwise from the 12 o'clock radius;

(iv) Along the radii, draw a bar for rainfall;

(v) For temperature, plot the points and join them with a curved line;

(vi) Choose the appropriate scale and remember that the vertical scale represents rainfall and temperature, while the horizontal scale represents months;

(vii) As clock graph is frequently used to represent climatic information; radii are scaled in °C. The scale is indicated on either the 12 o'clock or 6 o'clock radius. Points plotted are then joined as a continuous circle;

(viii) Bars can also be drawn along the radii to indicate monthly mean rainfall. In order to avoid congestion at the centre of the circle, zero is normally represented as a circle; and

(ix) Write the title, scale and key.

Example

Study the data provided in Table 3.42 and draw a polar chart.

Table 3.42: *Monthly mean rainfall (mm) and temperature (°C) in Tanzania in 2016*

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temp °C	28.4	28.9	29.8	27.9	27.9	27.3	26.8	28.1	28.5	29.9	29.6	28.5
Rainfall (mm)	191.8	131.2	140	213.6	41.1	9.2	2.2	8.3	14.1	27.8	64.6	66.6

Source: *Tanzania Meteorological Agency (2016)*

Solution:

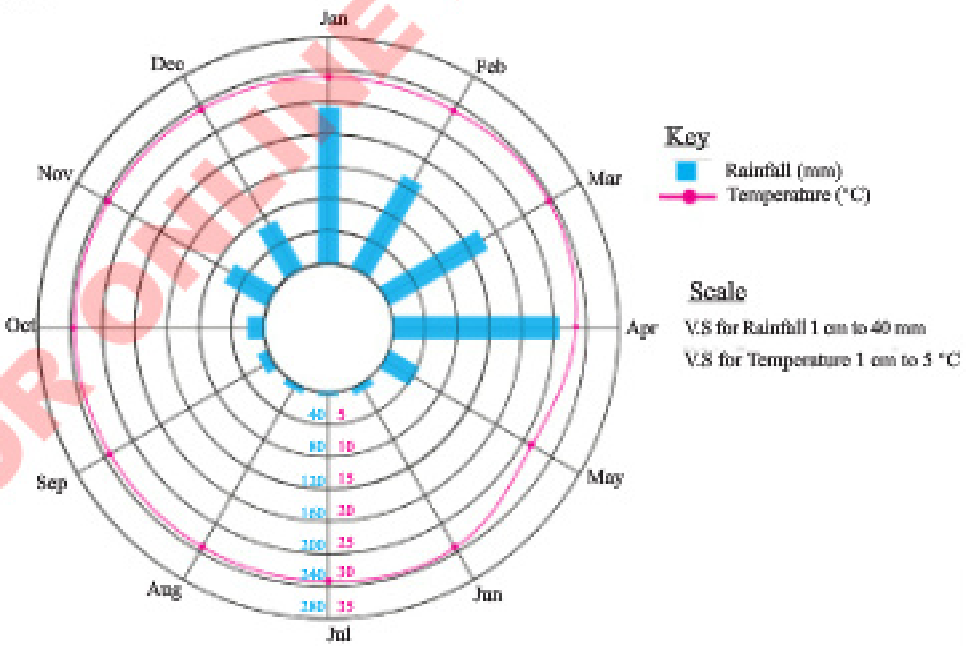


Figure 3.20: *Polar chart for monthly mean rainfall and temperature in Tanzania in 2016*

Advantages and disadvantages of polar charts in geographical research

Polar charts are beneficial in many ways. The common use is to guide the farmers by identifying their seasonal calender in a year. They can also be used in calculating monthly mean rainfall and temperature data. The chats are detailed by drawing two concentric circles. Some of their limitations include inability to display much of information, as they are squeezed in a circle. They are also time consuming as both organising the scale and drawing are complicated. Moreover, they are confined to weather conditions only.

Activity 3.3

1. Search for data on maize production in Tanzania between 2010 and 2020 and construct the following graphs:
   (a) Simple line graph
   (b) Simple bar graph
2. Collect data for production of three to five crops grown in your locality for the past three to five years. Use the data to construct the following graphs:
   (a) The compound line graph
   (b) The compound bar graph
3. Search for 2020 Tanzania population data by age and sex and construct:
   (a) Population pyramids using absolute values
   (b) Population pyramids using percentages

Charts and diagramatical methods

Geographical charts and diagrams method differ from graphical method as they do not depend on squared paper or a map in data presentation. Instead, they display data in circles, rectangles, repeated symbols, proportional diagrams, graduated symbols and wind roses. They may be used in conjunction with a map for the purpose of defining or describing a location but they can also be drawn independently. They are not necessarily drawn on a graph paper but even on plain or ruled papers.

There are six (6) major geographical charts and diagrams, these include: divided circles (pie charts), divided rectangles, repeated symbols, proportional diagrams, graduated range of symbols and wind roses.

Divided circle

A divided circle, also known as *pie chart,* refers to a diagram consisting of a circle divided into the slices which are proportional in size to the value represented. The slice of the circle may be shaded or coloured and labelled. The largest slice is plotted first clockwise from 12 o'clock in ascending order for easy comparison. The divided circle can be sub-divided into three parts, namely simple divided circle (pie chart), proportional divided circles and proportional divided semi-circles.

(a) Simple divided circle

It is a simple pie chart which is used to represent simple data such as exports, imports or production. Simple divided circle is also known as *simple pie chart*. The data in Table 3.43 has been used to draw Figure 3.21.

Procedures

(i) Find the total amount of all values as shown in Table 3.44;

(ii) Change each of the values into percentage, and then into degrees as shown in Table 3.44;

(iii) Draw a circle of a suitable radius;

(iv) Divide the circle into parts corresponding to the value of each degree of respective components. Drawing should be done clockwise from the 12`starting with the highest degree value;

The angles drawn will represent the respective percentages of the data items in the distributions. For example, 237.6° for 66% in the pie chart shown in Figure 3.21.

(v) Shade each potion differently; and

(vi) Write the title and the key.

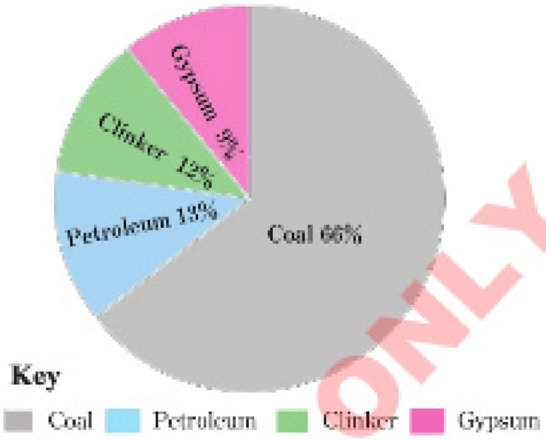


Figure 3.21: *Mineral imports in ('000) metric tonnes in Tanzania in 2015*

Note: The circle may be of any convenient size, too small circles must be avoided.

Solution

Table 3.43: *Mineral imports ('000) metric tonnes in Tanzania in 2015*

Mineral type	Weight in '000 tonnes
Coal	269
Gypsum	38
Petroleum	52
Clinker	50

Source: Ministry of Minerals (2015)

Table 3.44: *Percentage of mineral imports in ('000) metric tonnes in Tanzania in 2015*

Mineral type	Weight in '000 (X_i)	$\left(\frac{X_i}{\sum_{i=1}^{n} X_i}\times 100\%\right)$	$\frac{\%}{100\%}\times 360°$
Coal	269	66%	237.6°
Gypsum	38	9%	32.4°
Petroleum	52	13%	46.8°
Clinker	50	12%	43.2°
Total	**409**	**100%**	**360°**

Advantages and disadvantages of divided circles in geographical research

The main advantages of divide circles are that they are simple to construct, useful for comparison purposes as items can be clearly seen. They are easier to obtain accurate data presentation. The circles, however, have the following limitations: in case of zero degree, usually the data cannot be shown. Other limitations include accommodating limited data and they are time consuming due to calculations and drawing.

Another weakness is on their rigid method of data presentation which requires using pie charts only when total observation of the parts makes a meaningful whole. Pie charts are not recommended to use if the observations of different parts are not mutually exclusive.

(b) Proportional divided circle

It is a graph drawn in a circle whose radius is proportional to the total figures represented by all sectors of the circle. They are used for showing a quantity (for example, population of a country) that can be divided into parts such as different ethnic groups. A circle is drawn to represent the total quantity. Two or more circles are drawn in such a way that each one is proportional to the value it represents. The circle is then divided into segments which are proportional in size to the components. The actual size of the circle can also be used to represent data. The data in Table 3.45 has been used to draw Figure 3.22.

Procedures

(i) Find the total of each item under observation;

(ii) For each year, calculate the composition for each value in degrees;

(iii) Compute the radius for each by applying the square roots on each of the total items under observation;

(iv) Determine the scale to be used;

(v) Divide the calculated radii by the denominator of the scale to get the drawing radii;

(vi) Draw the circle based on the calculated radii;

(vii) Divide each circle into parts using degree values corresponding to the observed items; and

(viii) Write the title and key.

Example

Table 3.45: *Trend of some of the wild animals hunted from 2009 to 2012*

Year	Species				
	Elephant	Lion	Leopard	Hippopotamus	Buffalo
2012	41	37	40	40	53
2011	45	27	44	38	47
2010	96	98	205	158	1108
2009	98	120	249	153	1061

Source: *Ministry of Natural Resources and Tourism (2012)*

Table 3.46: *Trend and total number of some of the wild animals hunted from 2009 to 2012*

Year	Species					
	Elephant	Lion	Leopard	Hippopotamus	Buffalo	Total
2012	41	37	40	40	53	211
2011	45	27	44	38	47	201
2010	96	98	205	158	1108	1665
2009	98	120	249	153	1061	1681

Table 3.47: *Composition of some of the wild animals hunted from 2009 to 2012 in degrees*

Year	Species				
	Elephant	Lion	Leopard	Hippopotamus	Buffalo
2012	$\frac{41}{211}\times 360^\circ = 70^\circ$	$\frac{37}{211}\times 360^\circ = 63^\circ$	$\frac{40}{211}\times 360^\circ = 68^\circ$	$\frac{40}{211}\times 360^\circ = 68^\circ$	$\frac{53}{211}\times 360^\circ = 90^\circ$
2011	$\frac{45}{201}\times 360^\circ = 81^\circ$	$\frac{27}{201}\times 360^\circ = 48^\circ$	$\frac{44}{201}\times 360^\circ = 79^\circ$	$\frac{38}{201}\times 360^\circ = 68^\circ$	$\frac{47}{201}\times 360^\circ = 84^\circ$
2010	$\frac{96}{1665}\times 360^\circ = 21^\circ$	$\frac{98}{1665}\times 360^\circ = 21^\circ$	$\frac{205}{1665}\times 360^\circ = 44^\circ$	$\frac{158}{1665}\times 360^\circ = 34^\circ$	$\frac{1108}{1665}\times 360^\circ = 24^\circ$
2009	$\frac{98}{1681}\times 360^\circ = 21^\circ$	$\frac{120}{1681}\times 360^\circ = 26^\circ$	$\frac{249}{1681}\times 360^\circ = 53^\circ$	$\frac{153}{1681}\times 360^\circ = 33^\circ$	$\frac{1061}{1681}\times 360^\circ = 227^\circ$

The radii of the two circles are determined by: $Radius(R) = \sqrt{T}$

Where;

T = the total value of the given item

$$R_1 = \sqrt{211} = 14.52$$

$$R_2 = \sqrt{201} = 14.17$$

$$R_3 = \sqrt{1665} = 40.80$$

$$R_4 = \sqrt{1681} = 41$$

Scale: Let 1cm represent 10 units (cm)

Divide the calculated radii by the denominator of the scale to get the drawing radii as follows:

14.52÷ 10 = 1.4 cm

14.17 ÷ 10 = 1.4 cm

40.80 ÷ 10 = 4 cm

41 ÷ 10 = 4.1 cm

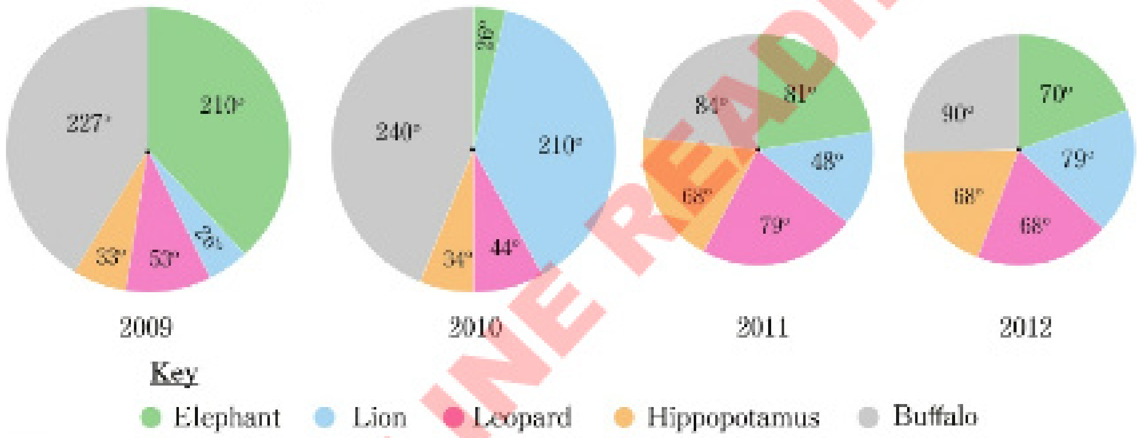


Figure 3.22: *Proportional divided circles showing trend of some of the wild animals hunted from 2009 to 2012 in degrees.*

Advantages and disadvantages of proportional divided circles in geographical research

The proportional divided circles are beneficial in a number of ways including displaying relative proportions of multiple classes of data. The size of the circle can be constructed proportionally to the quantity of data it represents. The circles are also useful in summarising a large data set in visual form and they are simple compared to other forms of graphs. They also allow visual checking of the accuracy of the calculations. However, divided circles are associated with limitations such as failure to easily reveal the exact values and that they can be easily manipulated to give false impressions.

Divided semicircles

These are partitioned half circles. There are two kinds of divided semicircles. These are, simple divided semicircles and proportional divided semicircles.

Simple divided semicircles

These are semi circular in nature, but segmented accordingly. The segmentation is guided by 180 degrees instead of 360 degrees as used in pie charts (Figures 3.23 & 3.24).

Procedures

The procedures for constructing simple divided semicircles are similar to those of drawing simple piecharts, except that the degrees are obtained by using 180 degree instead of 360 degrees.

Example

Using the data in Table 3:48, draw a simple divided semi-circle to represent the number of lions hunted from 2009 to 2012.

Solution

Find the total of items

Total = 37 + 27 + 98 + 120

Total = 282

To find the radius $\sqrt{282}$

= 16.79

Scale: Let 1 cm represent 3 units (cm)

Then,

$$\frac{16.79}{3} = 5.5 \text{ cm}$$

Hence, radius = 5.5 cm

To find degree (180°) for each year

$$2012 = \frac{37}{282} \times 180° = 23.61°$$

$$2011 = \frac{27}{282} \times 180° = 17.23°$$

$$2010 = \frac{98}{282} \times 180° = 62.55°$$

$$2010 = \frac{120}{282} \times 180° = 76.59°$$

Draw a divided semicircle to segment them accordingly. The segment should be portioned in a clockwise direction as in simple pie charts.

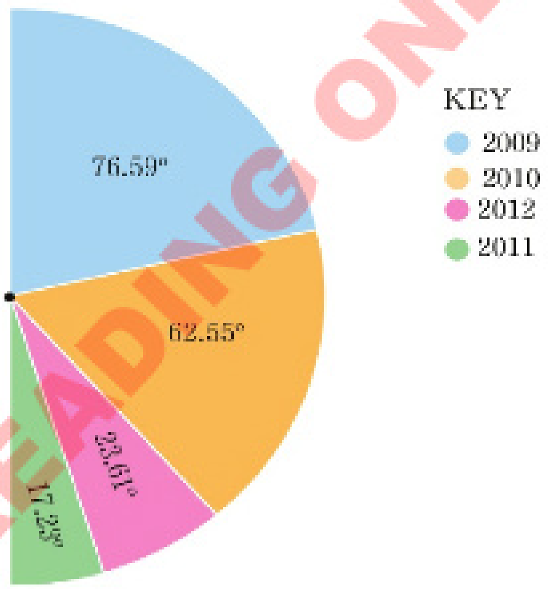


Figure 3.23: *A simple divided semicircle representing the number of lions hunted from 2009 to 2012*

Proportional divided semicircle

Proportional divided semicircles are used to represent two data set in one circle, half circle for each data set.

Procedures

The following are procedures for drawing proportional divided semi-circles:

(i) Calculate the total of each data set;

(ii) Find the radius of the semicircle corresponding to the data set;

(iii) Determine the scale of each semicircle first, then divide the radii by the scale denominator to get the drawing radii;

(iv) Use the two radii to determine the size of semi-circles;

(v) Express each semi-circle by percentage or proportional divided semicircles using the degree values in either ascending or descending order;

(vi) Draw the proportional divided semi-circle using the degree values in either ascending or descending order; and

(vii) Write the title and key.

Example

Table 3.48: *Gypsum production and export in '000 tonnes in Tanzania from 2013 to2016*

Year	Production ('000 tonnes)	Export ('000 tonnes)
2016	214	214
2015	255	225
2014	200	200
2013	281	172

Source: *Ministry of Minerals (2016)*

Solution

Table 3.49: *Total of gypsum production and export in '000 tonnes in Tanzania from 2013 to2016*

Year	Production ('000 tonnes)	Export ('000 tonnes)
2016	214	214
2015	255	225
2014	200	200
2013	281	172
Total	**950**	**811**

The radii of the two circles are determined by:

Radius (R) $=\sqrt{T}$

Where;

T = the total value of the given item

Find the total of every item. The totality for the first item is 950 and the total for the second item is 811.

Find the radius for both totals.

$R1 = \sqrt{950} = 30.82$

$R2 = \sqrt{811} = 28.48$

Scale: Let 1 cm represent 10 units (cm)
30.82 ÷ 10 = 3.1 cm

28.48 ÷ 10 = 2.8 cm

Table 3.50: *Gypsum production and export in '000 tonnes in Tanzania from 2013 to 2016 in degrees*

Year	Degrees	
	Production ('000 tonnes)	Export ('000 tonnes)
2016	$\frac{214}{950} \times 180° = 41°$	$\frac{214}{811} \times 180° = 48°$
2015	$\frac{255}{950} \times 180° = 48°$	$\frac{225}{811} \times 180° = 50°$
2014	$\frac{200}{950} \times 180° = 38°$	$\frac{200}{811} \times 180° = 44°$
2013	$\frac{281}{950} \times 180° = 53°$	$\frac{172}{811} \times 180° = 38°$

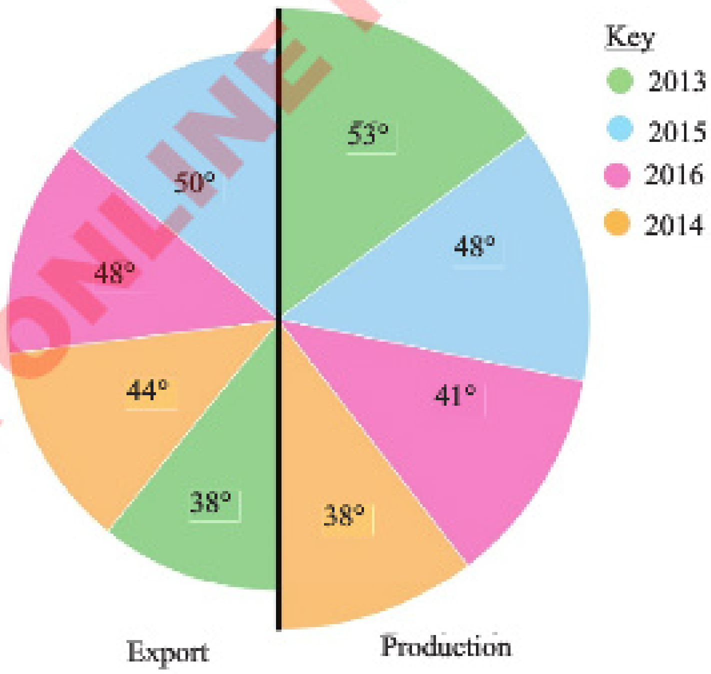


Figure 3.24: *A proportional divided semicircle showing gypsum production and export in Tanzania from 2013 to 2016*

Advantages and disadvantages of proportional semicircle in geographical research

Proportional semicircles, are used in making comparison, that is why two semicircles are used. The value of each component can be analysed to provide accurate geographical information through percentages or degrees calculated. However, the method has some limitations including time consuming during calculations. On the other hand, the actual values may not be known easily as calculations involve percentages or degrees. Additionally, presentation of very small values cannot be accommodated by the method since their clarity can be distorted.

Divided rectangle

It is a rectangle whose total value or quantity is sub-divided into its constituents or parts. The divided rectangle is similar to compound bar graphs and even the procedures for drawing are the same. Divided rectangles can be categorised into two major groups, namely, simple divided rectangle and compound divided rectangle.

Simple divided rectangle

This is a single bar graph which is large in size. The bar is subdivided into divisions or parts depending on the data given. The data in Table 3.51 has been used to construct Figure 3.25.

Procedures

The following are procedures for constructing a simple divided rectangle:

(i) Find the total values of all items in the table and arrange the item values according to their size, starting with the largest as shown in Table 3.36(b);

(ii) Change each item value into percentage; select the suitable length of the rectangle, width does not matter, but it should be smaller than the length. For example, let 1 cm represent 7%. Hence, the length of rectangle will be 14.3 cm;

(iii) Use the percentage composition of each value to calculate unit lengths from the total horizontal length;

(iv) Each unit length should be carrying percentage composition of each value;

(v) Draw the rectangle subdivided into parts and shade each part differently starting with the smallest; and

(vi) Write the title and key.

Example

Table 3.51. *Production of perennial crops (000 tonnes) in Tanzania in 2012*

Crop	Production
Coffee	995
Sisal	58
Cane sugar	57
Cashew nuts	152
Tea and pyrethrum	18

Source: *Ministry of agriculture (2012)*

Solution

Table 3.52: *Production of perennial crops ('000 tonnes) in Tanzania in 2012*

Crop	Production ('000 tonnes)	Percentage (%)	1cm = 7% X cm = ?	Cumulative length
Coffee	995	77.73	11.1	11.1
Sisal	152	11.88	1.7	12.8
Sugar cane	58	4.53	0.65	13.45
Cashew nut	57	4.45	0.64	14.09
Tea and pyrethrum	18	1.41	0.20	14.29
Total	**1280**	**100**		

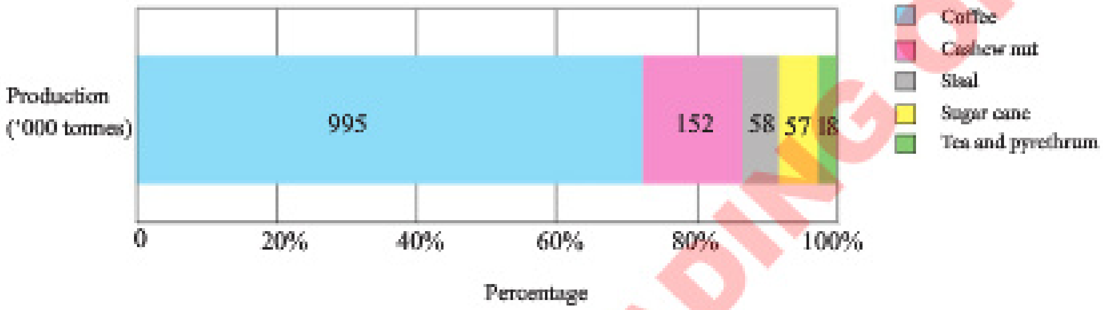


Figure 3.25: *Simple divided rectangle showing production of perennial crops ('000 tonnes) in Tanzania in 2012*

Advantages and disadvantages of simple divided rectangles in geographical research

The simple divided rectangle is convenient in presenting data on a diagram due to its simple scale. Only the scale for dependent variable is considered. The rectangle is not associated with application of complicated calculations, hence easily drawn.

Moreover, the information displayed allows easy comparison of information given in the diagram. It also presents numerous items with better visualisation due to colouring of the diagram which is attractive. Nonetheless, simple divided rectangle falls short of presenting few data as compared to the compound divided rectangle. Furthermore, the vertical scale is not considered when drawing the independent variable.

Compound divided rectangle

This is a type of a divided rectangle which involves more information as it presents several data as shown in Figure 3.25. The rectangle can be employed in describing land uses in different countries, states, regions or districts. Often, the information can be visualised simultaneously for comparison purposes in terms of extent and variations across the studied elements. The data in Table 3.53 has been used to draw Figure 3.26.

Procedures

The following are procedures for drawing a divided rectangle:

(i) Find the total of each number of items which is used to determine the horizontal scale;

(ii) Calculate the % of each number of items;

(iii) Find the horizontal scale using the grand total from sub-totals on procedure (i) scale that is the total length of horizontal baseline;

(iv) Calculate the portion or segment for each number of items given basing on the horizontal scale, that is, the total length of horizontal baseline; and

(v) Calculate the vertical scale depending on the percentage of such items.

Example

Table 3.53: *Number of small scale industries established in Songwe region by 2015*

Council	Welding	Carpentry	Maize milling	Sunflower processing	Total number of industries
Songwe DC	6	5	124	7	142
Ileje DC	15	75	216	11	317
Mbozi DC	79	374	646	55	1 154
Momba DC	4	1	214	3	222
Tunduma TC	54	104	128	10	296

Source: *Songwe Region (2019)*

Solution

Table 3.54: *Total number of small scale industries established in Songwe region by 2015*

Council	Welding	Carpentry	Maize milling	Sunflower processing	Total number of industries
Songwe DC	6	5	124	7	142
Ileje DC	15	75	216	11	317
Mbozi DC	79	374	646	55	1 154
Momba DC	4	1	214	3	222
Tunduma TC	54	104	128	10	296
				Grand total	**2131**

Table 3.55: *Percentage of the number of small scale-industries established in Songwe region by 2015*

Council	Number of industries	Percentages				
		Welding	Carpentry	Maize milling	Sunflower processing	Total
Mbozi DC	1154	7	32	56	5	100
Ileje DC	317	5	24	68	3	100
Tunduma TC	296	18	35	43	4	100
Momba DC	222	2	1	96	1	100
Songwe DC	142	4	4	87	5	100

From Table 3.37 (a), then,

Total area (grand total)

$$= 142 + 317 + 1154 + 222 + 296 = 2131 \text{ units}$$

From the grand total, estimate the horizontal scale.

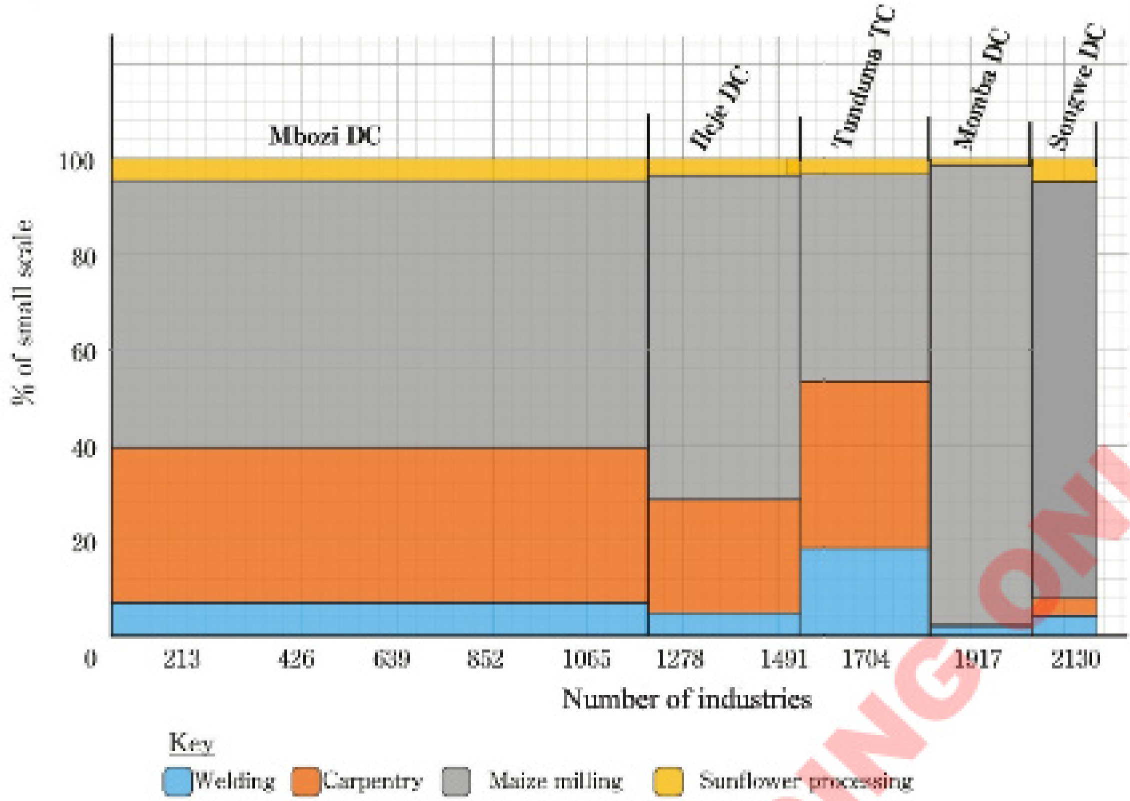
$$\frac{2\,131}{10} = 213.1 \text{ units}$$

The diagram may extend to 10 cm horizontally it will be; 1 cm: 213.1 units.

Table 3.56 : *Portion for small scale-industries established in Songwe region by 2015*

Council	Unit length	Cumulative length
Mbozi DC	$\frac{1154}{213.1} = 5.4$ units	5.4 units
Ileje DC	$\frac{317}{213.1} = 1.5$ units	6.9 units
Tunduma TC	$\frac{296}{213.1} = 1.4$ units	8.3 units
Momba DC	$\frac{222}{213.1} = 1.0$ units	9.3 units
Songwe DC	$\frac{142}{213.1} = 0.7$ units	10 units

The vertical scale depends on percentages calculated for each council. Present the data from each council depending on the vertical scale which is usually 1 cm: 20% as shown in Figure 3.26.



Scale: V.S:1cm to 20%; H.S:1cm to 213 Km^2

Figure 3.26: *Compound divided rectangle showing the number of small scale industries established in Songwe region by 2015*

Advantages and disadvantages of compound divided rectangles in geographical research

The compound divided rectangle is useful in the following ways. Firstly, it can convey much more geographical information than a compound bar graph and a divided circle. The comparison of data can be easily visualised and interpreted. Furthermore, it is capable of displaying for example, area in square kilometres in relation to economic activities. However, its limitations include the methods being too tedious in calculating and identifying the scale which should be compromised between vertical and horizontal scale. It is also time consuming due to complex procedures used to access data for constructing the graph.

Repeated symbols

Symbols are simple signs that are used to represent different features. Since maps require large amounts of information to be conveyed in a limited space, the use of symbols to represent particular features is necessary. Symbols are small but many are immediately recognisable. This means that they have an advantage over drawing or writing all of this information onto a map.

Repeated symbols is a method in which geographical information can be represented on a map by the repetition of one symbol of uniform size or character or by a variety of symbols placed on their location on a map. Therefore, two types of repeated symbols can be distinguished, namely qualitative and the quantitative symbols. Repeated symbols are the simplest methods of conveying geographical and non-geographical information on a map and they are commonly observed on maps dealing with agricultural products, minerals, economic development and maps and guides generated for specific purposes, for example, tourism for promotion purposes.

The qualitative symbols

They are basically pictorial or descriptive in nature. Examples include crops by their initial letters such as **CN** for cotton, **CF** for coffee, **SS** for sisal, **CL** for clove and **P** for palm oil (Figure 3.27). Others are illustrations of plants for crops, drawings of cattle for ranching, pictures of trees for forests or a range of symbols for minerals and so on. The symbols can either be pictorial or descriptive. The qualitative repeated symbols are essentially descriptive devices which give a visual impression of the represented data item. They do not represent the actual characteristics of the observed variable.

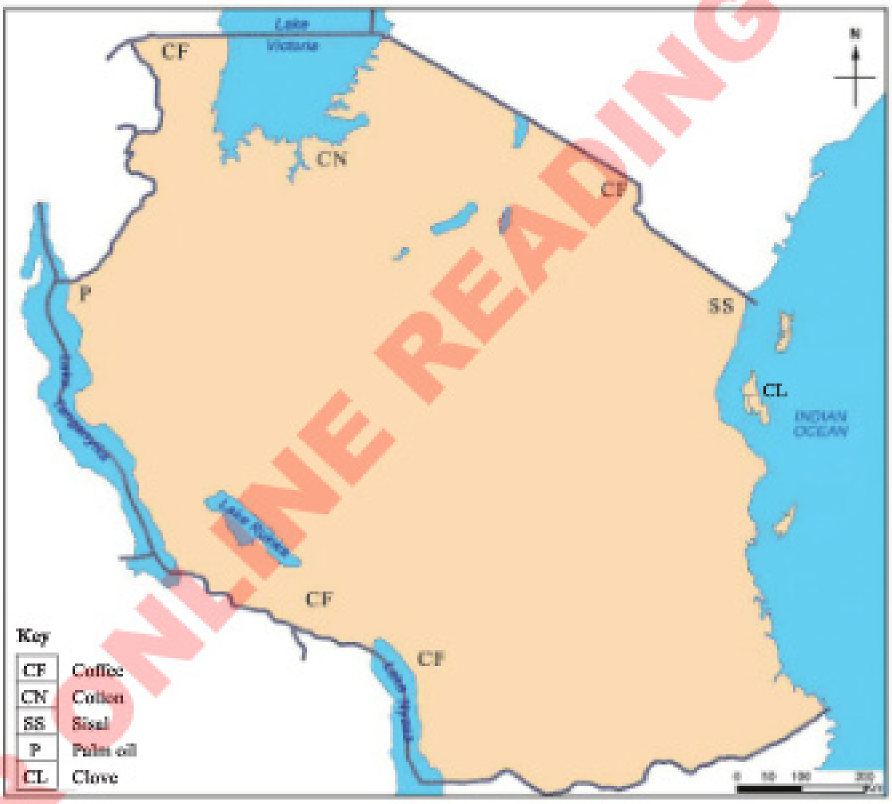


Figure 3.27: *Cash crops production in Tanzania*

Quantitative symbols

These are symbols of the same size and shape placed on a map to show the quantity of what the symbol represents. Each symbol represents a given quantity. For example, one fish can represent 10,000 tonnes of fish. Therefore, the number of fish on a map is counted and then multiplied by 10,000 to get the total amount of tonnes (Figure 3.28).

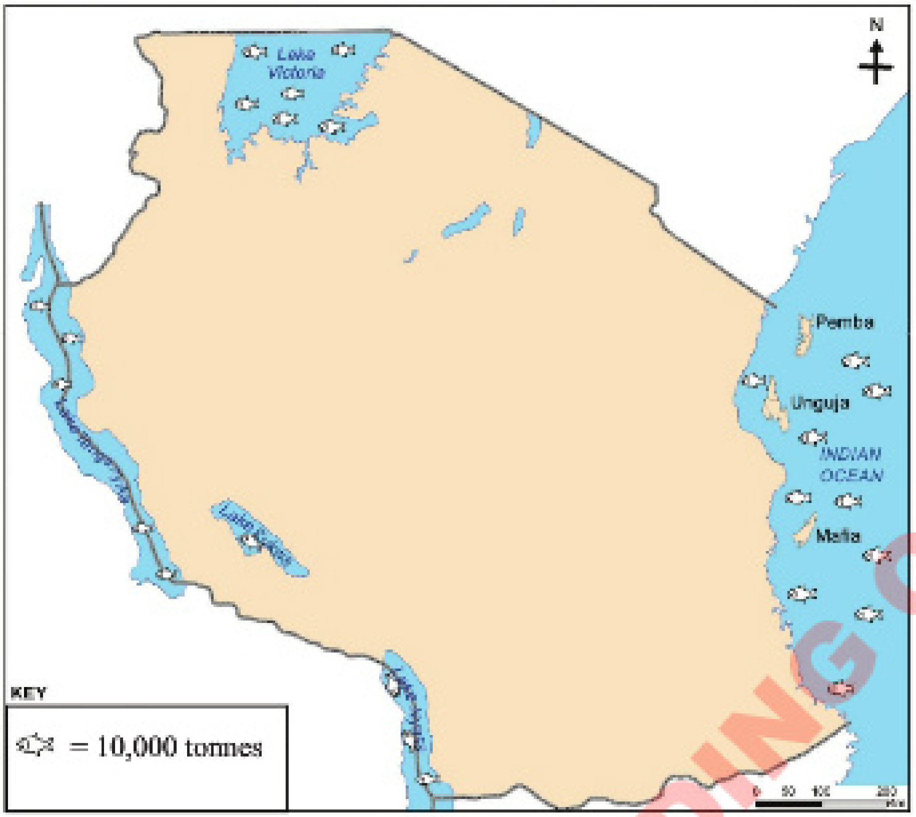


Figure 3.28: *Quantity of fish in '000 tonnes in Tanzania's water bodies*

Advantages and disadvantages of repeated symbols in geographical research

Repeated symbols have both advantages and disadvantages. Some of the benefits of the symbols include their usefulness in presenting geographical information which is easy to read and interpret; and simplifying comparison of the presented data items such as economic production related data. Simple construction of the scale and the use of calculation is minimised in the cases of qualitative symbols. On the other hand, the symbols have some drawbacks such as; limitations of drawing symbols of the same size by free hand. The needs for drawing a sketch map may be difficult. The limited use of scale especially in qualitative approach may cause problems in understanding the actual product in terms of amount. Another drawback with repeated symbols is congestion or overlap, especially if there are large variations in the size of symbols and if numerous data locations are close.

Proportional diagrams

A proportional diagram is a figure that compares two or more values by using the area of shapes, usually in the form of squares, rectangles, or circles. They are popular because they instantly communicate the differences in the values to a viewer. These diagrams are commonly used in newspapers and magazines. The proportional diagrams can be regarded as an extension of the proportional divided circles (pie chart). Proportional diagrams can be presented in four (4) ways, which are proportional circles, squares, cubes and sphere.

Proportional circles

Proportional circles can be used to represent various items, for example population, crop yields, quantities of imported and exported goods. The scale is drawn to show the value of a given circle. Usually, each circle is proportional to the quantity it represents.

Procedures

The following are procedures for drawing proportional circles:

(i) Find the square roots of each item of data that will denote a radius of the circle;

(ii) Estimate the length of the radius for the largest circle first. For example, if the population of a village is 3000 people, the square root will be 54.7. Therefore, it should be noted that the radius of 54.7mm could be too large to draw;

(iii) Thus, it should be halved, it may be suitable at 27.3mm;

(iv) For this case, all other radii must also be halved;

(v) The proportional circle will be drawn in the ascending order by starting with that of the smallest circle to the largest, depending on the number of data items;

(vi) Label each of the circles with a respective quantity represented by the proportional circle; and

(vii) Indicate the unit of the items represented and a scale.

Example

Draw a proportional circle showing the trend of gazelles hunted from 2009 to 2012.

Table 3.57: *Number of gazelles hunted from 2009 to 2012*

Year	Gazelle
2012	40
2011	44
2010	205
2009	249

Table 3.58: *Radius of circles showing the number of gazelles hunted from 2009 to 2012*

Year	Gazelle	Square root	Radius
2012	40	6.3	$\frac{6.3}{7} = 0.9$ cm
2011	44	7.6	$\frac{6.6}{7} = 0.9$ cm
2010	205	14.3	$\frac{14.3}{7} = 2.0$ cm
2009	249	15.8	$\frac{15.8}{7} = 2.3$ cm

Since the square root has a low amount of value, let the estimated radius be 1cm representing 7 items number of square roots.

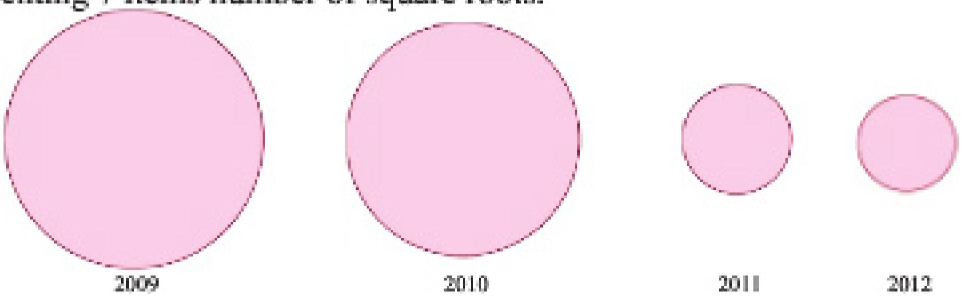


Figure 3.29: *Proportional circle showing the number of gazelles hunted from 2010 to 2012*

Advantages and disadvantages of proportional circles in geographical research

The proportional circle is essential for making comparison of the data items under the study. It can be combined with other methods in the same map. The method can also be used where other methods such as dots may result in overcrowding. The cycle has some limitation such as difficulties in making comparison when the size of circles are almost the same due to small differences of represented values. Other limitations involve time consumption due to the long processes of scale calculation. Again, the method falls short of presenting absolute values.

Proportional squares

Proportional squares may be used in the same way as proportional circles. The area of the square proportionally reflects the quantity it represents. On the other hand, the length of the side of the square related to the square root reflects directly the square root of the number to be represented. This method is useful in cases where there are relatively high values to be dealt with, such that by applying the square roots, numbers are reduced and become manageable. Proportional squares may be employed without reference to the map.

Procedures

The following are procedures for the construction of proportional squares:

(i) Calculate the square root of the total which will act as the length of sides for the square;

(ii) Draw the square representing the identified variables;

(iii) In cases of super-imposition of the squares with other geographical information, make sure that the South-west touches the point of the represented item under the study;

(iv) The proportional square can be drawn independently on maps, that is, in absence of super-imposition; and

(v) Show the key clearly.

Advantages and disadvantages of proportional squares in geographical research

Even though the proportional squares are more difficult to draw, their relative areas are probably easier to assess than circles; and are more suitable for comparison of items under observation.

Proportional cubes

Proportional cubes can be drawn independent of a base map. They are usually located on a base map as representative of quantity distribution or production. Cubes have additional component on dimensions, that is, length × width × height which differentiate them from rectangles. Cubes have a strength of presenting geographical information which have greater values as compared to linear methods. The side of the proportional cube bears a direct relationship to the square root of the quantity being represented. For instance, if the length of the side of the proportional is square 5 mm, it means it represents 25 units of production while a cube of the same measurements will represent 125 units.

Procedures

The following are procedures for constructing proportional cubes:

(i) Calculate the cube root of the quantity to be represented such as $\sqrt[3]{R}$, where R is the quantity to be represented;

(ii) Draw the cubes independently of the base-map, for the purposes of comparison;

(iii) Cubes can be drawn in several ways either *isometrically,* in which all sides are of equal lengths, or *prospectively* in which the sides are one-halved to three quarters the length of the front. In a single map, all drawn cubes should be with same pattern; and

(iv) Provide a key and scale.

Advantages and disadvantages of cubes in geographical research

The advantage of proportional cubes is that it is easy to draw than spheres and the assessment of the volume of two cubes of different sizes is perhaps less difficult than the relative volumes of two different spheres. Proportional cubes are however disapproved for less visualisation, unless the presented items by themselves have a cube-shaped like bales of cotton. Another disadvantage is that the components of the cube cannot be split. Moreover, the use of cubes is limited in making comparison of the quantities being represented, unless geographical information is provided on the cube.

Proportional sphere

Usually, the concept of proportional sphere is somewhat similar to the concept to the proportional cube. Likewise, the three-dimension characteristics possessed by the spheres widens that horizon of serving nearly the same purpose as the cube. Three dimensions enable it to accommodate a wide range of values to be represented, the volumes of the sphere are usually proportional to the quantity represented.

Procedures

The following are procedures for the drawing proportional spheres:

(i) Make sure you calculate the cube root of the item under observation; this can be in terms of quantity or the total to be presented;

(ii) The drawn sphere should be placed in the same straight line for the sake of comparing;

(iii) In case spheres are used in the base map, you must maintain the same pattern of constructing each sphere;

(iv) The quantities in terms of sphere should be indicated in each sphere; and

(v) The key and the scale should be indicated.

Advantages and disadvantages of proportional spheres in geographical research

Proportional spheres enable easier visualisation of items under the study same as proportional cubes. They serve as alternative options in incidents of great quantity of elements which becomes impractical on other methods. However, the sphere has some disadvantages including difficulty in drawing, calculations challenges and limitations of some readers to assess relative volumes of different spheres.

Activity 3.4

Choose any region in Tanzania and collect data on the production of three to five crops for the past three to five years. Use the collected data to construct a simple divided circle (simple pie chart).

Wind roses

Wind roses are used to show the average frequency and directions of the wind in different speeds at a given area. They can also be used to show the delivery of quantities such as milk, newspapers or other goods through star diagram. Wind roses are of two types, namely; simple wind roses and compound wind roses.

Simple wind rose

A simple wind rose is a simple linear method used to show the direction and frequency of the wind only.

Procedures

The following are procedures for drawing a simple wind rose:

(i) Normally, start by drawing a circle of any convenient size which will mark the centre of a wind rose;

(ii) The calm days should be indicated into the circle;

(iii) Draw a wind rose based on the eight cardinal points often regard to be sufficient;

(iv) The length of the columns or arms should be drawn proportional to the actual number of days; and

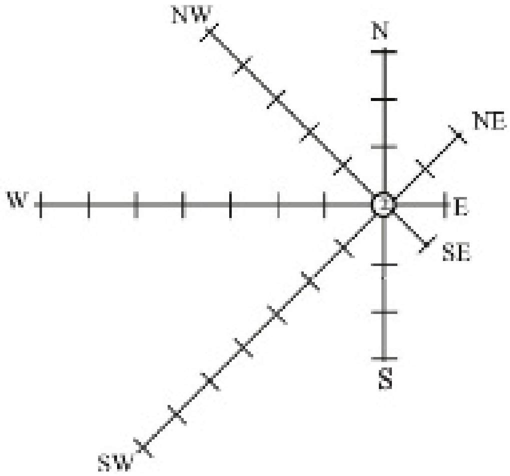
(v) Draw the simple wind rose; indicate the title and scale.

NB: The average wind speed and direction values are recorded monthly or annually.

Example: Study the data given in Table 3.59 and draw a simple monthly wind rose.

Table 3.59: *Monthly wind hypothetical station X*

Direction of wind	Number of days
N	3
NE	2
E	1
SE	1
S	3
SW	7
W	7
NW	5
Calm	2



Scale: 1cm to 1 unit

Figure 3.30: *Simple wind roses showing monthly wind direction*

Compound wind rose

Compound wind roses may be used to display wind direction, frequency and speed.

Procedures

The following are procedures for drawing a compound wind rose:

(i) The basic method of construction is similar to that of simple wind rose, only that compound wind rose uses either actual or percentage values;

(ii) The speed of the wind is then indicated by adjusting the width of the column. An increase in width signifies an increase in wind speed;

(iii) The divisions chosen are usually less than 4 mph;

(iv) When it is calm, the force is zero (0) and the speed is less than 1mph;

(v) Compose a convenient scale for depicting the number of hours per direction;

(vi) Determine the pattern of speed as a key; and

(vii) Plot diagram and put a good title.

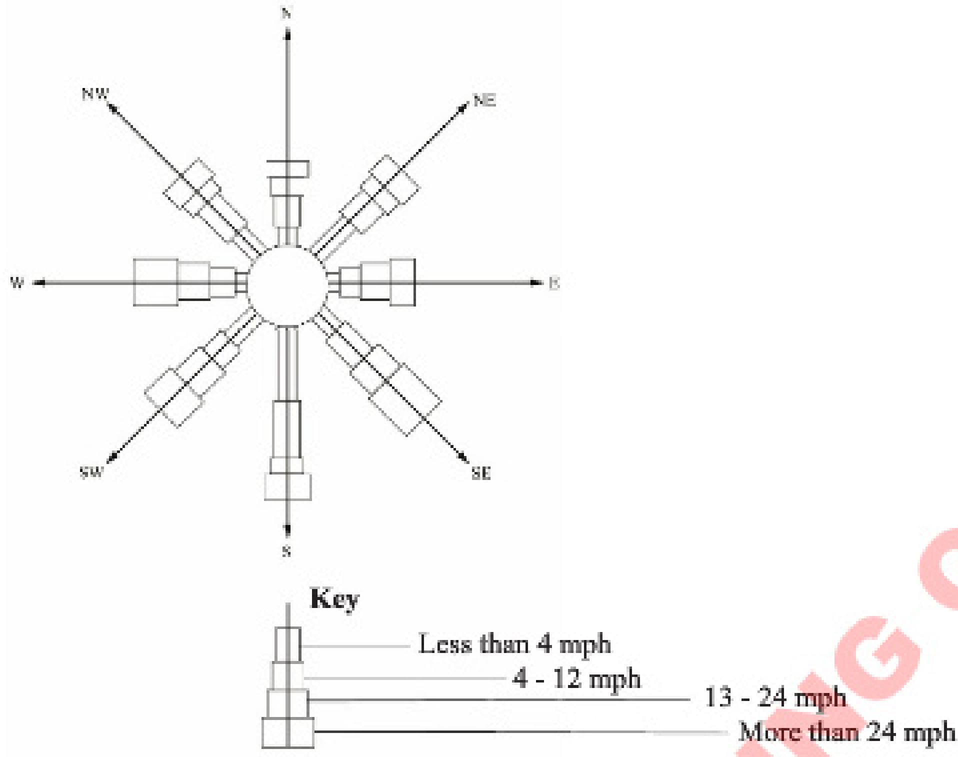
Note: Much attention is needed in drawing and in scale selection.

Example:

Table 3.60 shows the mean annual wind speed and direction for hypothetical station X.

Table 3.60: *Mean annual wind speed and direction for hypothetical station X*

Wind speed	N	NE	E	SE	S	SW	W	NW
Less than 4 mph	1.2	4.2	1.1	2.1	6.2	3.3	1.2	3.3
4 – 12 mph	2.8	3.0	1.6	4.2	5.0	2.4	2.4	3.9
13 – 24 mph	1.8	1.4	3.0	3.3	1.1	4.1	3.3	1.2
More than 24 mph	1.0	2.0	2.1	6.1	2.3	3.1	3.9	2.4
Total	**6.8**	**10.6**	**7.8**	**15.7**	**12.6**	**12.9**	**10.8**	**10.8**



Scale: 1cm to 1unit

Figure 3.30: *Mean annual wind speed and direction for hypothetical station X*

Advantages and disadvantages of wind rose in geographical research

The pattern of shading gives the diagram a good visual impression. Comparison is easy in terms of the direction in which the wind blows. It shows the speed of the wind in different directions. However, wind rose has some demerits such as time consuming since it involves measuring and scale construction.

Activity 3.5

Draw a compound wind rose to represent the following data:

Wind speed		Direction
Less than 4 mph	6 mm	N
4 – 12 mph	8 mm	E
13 – 24 mph	10 mm	W
More than 25 mph	12 mm	S

Exercise 3.3

1. The production of tea in the two hypothetical regions X and Y for 2015, 2016 and 2017 is shown in the table below.

Year	Region X	Region Y (000)
2015	450	900
2016	600	780
2017	690	840

Draw the proportional divided semicircle to compare production in the two hypothetical regions.

2. On the map of Tanzania, use a non-qualitative symbol to show the location of two mineral resources of your choice.

Map methods

Map methods is another way of data presentation in geography whereby geographical data can be presented through a sketch map. Map methods are classified into four (4) groups, namely; dot maps (distribution of maps), isoline maps (isopleth maps), chloropleth maps (shading or destiny maps) and flow line maps (flow maps).

Dot map

Dot map is the simplest and most widely used type of distribution maps that uses a point to visualize the geographical distribution of a phenomena. The dot map results from a combination of repeated symbols of uniform size and a dispersion map. A distribution map is essentially the representation of absolute or actual quantities on a map in such a way that a single quantitative dot has a specific and fixed value of a quantity represented. Therefore, it is imperative (though not always practical) to count the number of dots on a map and multiply with the quantity they are assigned to for accurate estimation of the total value.

Construction of dot maps

The construction of dot maps (distribution dot maps) is established by the components, namely, dot value, size, location and followed by drawing. Deciding on dot-value can possibly affect the representation of quantity on a map, so it should neither be undermined nor exaggerated. This means that, if not carefully considered, it would result into unnecessary placing of too many dots while the dot-value is too low (overcrowded maps), especially in areas with greater concentration. Similarly, placing too few dots where the dot-value is too high could give an equally wrong impression. Decision on dot map should be guided by the range of figures to be represented that has implication to the value and number of dots to be drawn. It is recommended to prepare a trial map which despite consuming time, will guide you through to obtain reliable results.

Dot size in terms of its diameter is important. Dot size cannot be thought in isolation with the dot-location. Extreme sizes of dots should be avoided, the number and size of dots must be in a way that they give a clear visual impression of the differences in distribution, contrasting with regard to the varying concentration across areas such as areas with greater concentration versus sparsely or scattered areas.

Dot location is however concerned with placing the dots based on two methods, namely, distributing evenly over the area concerned or based on quantities represented by the precise location of the dots on a map. The former is of limited value although it can be resorted to in case of absence of precise distribution of the dots on a map.

In this method, dots are evenly distributed after calculation of the number of dots. This method falls short of conveying limited information except the total quantity (the number and value of dots) and it is impractical in indicating the possible true distribution of the dots. It is however useful in presenting the visual impression of comparative densities.

For the case of the latter method, consideration is on the prior first-hand information of the area. However, in the absence of first-hand information, it relies on other reasonably accurate maps of the same area. For instance, maps showing relief, drainage, geology, soils, vegetation, rainfall, land use, communication, water supply and settlements. Basing on analysis and collating of such information gives hints though not perfectly accurate on possible areas to be distributed with either scarce or concentrated kind of dots. In case of concentrated areas, it is advised to address those areas first by calculating the number of the required dots and thereafter completing the rest of the dots in other areas.

Importantly, drawing the dots can be unclear, particularly to non-professionals. However, preparation should thoroughly be done by marking on the map the position of all dots, very slightly, with a special pencil. Some of the recommended materials for drawing are dotting pens, since the subsequent drawing of dots with correct size, circular and uniform character, cannot be done successfully with an ordinary pen or pencil. Probably the non-professionals are advised to use fibre or nylon-tipped pens which are commonly available and affordable. A good drawing result can be achieved by a firm and vertically held pen on the non-absorbent paper. The data in Table 3.61 have been used to draw Figure 3.32.

Procedures

The following are the procedures for constructing dot maps:

(i) Calculate the scale by identifying the dot value;

(ii) Determine the size of a dot whereby too a large or small dot is not appropriate;

(iii) Draw the sketch map where dots will be allocated; and

(iv) Prepare an appropriate scale. For example, let 1 dot represent 300 people.

Example

Study the data in Table 3.62 and draw a dot map showing a hypothetical number of antelopes in the selected gazetted national parks in Tanzania.

Table 3.62: *Hypothetical number of antelopes in the selected gazetted national parks in Tanzania by 2019.*

S/N	The National Park	Number of antelope
1	Katavi	4471
2	Kilimanjaro	1668
3	Mahale	1613
4	Mikumi	3230
7	Mkomazi	3254
6	Ruaha	20300
7	Saadani	1062
8	Serengeti	14763
9	Tarangire	2830
10	Udzungwa	1990

Solution

Scale: Let 1 dot represent 500 antelopes

Then, the number dots representing the number of antelopes in each national park is calculated as shown in Table 3.63.

Table 3.63: *Number of dots representing number of antelopes in the selected gazetted national parks in Tanzania by 2019*

S/N	The National Park	Number of antelope	Calculations	Average	Number of dots
1	Katavi	4471	4471 ÷ 500	8.94	9
2	Kilimanjaro	1668	1668 ÷ 500	3.34	3
3	Mahale	1613	1313 ÷ 500	3.23	3
4	Mikumi	3230	3230 ÷ 500	6.46	6
5	Mkomazi	3254	3254 ÷ 500	6.51	7
6	Ruaha	20300	20300 ÷ 500	40.60	41
7	Saadani	1062	1062 ÷ 500	2.12	2
8	Serengeti	14763	14763 ÷ 500	29.53	30
9	Tarangire	2830	2830 ÷ 500	5.66	6
10	Udzungwa	1990	1990 ÷ 500	3.98	4

Finally, for each National Park on the map of Tanzania, mark all dots corresponding to the number of antelopes as shown in Figure 3.31.

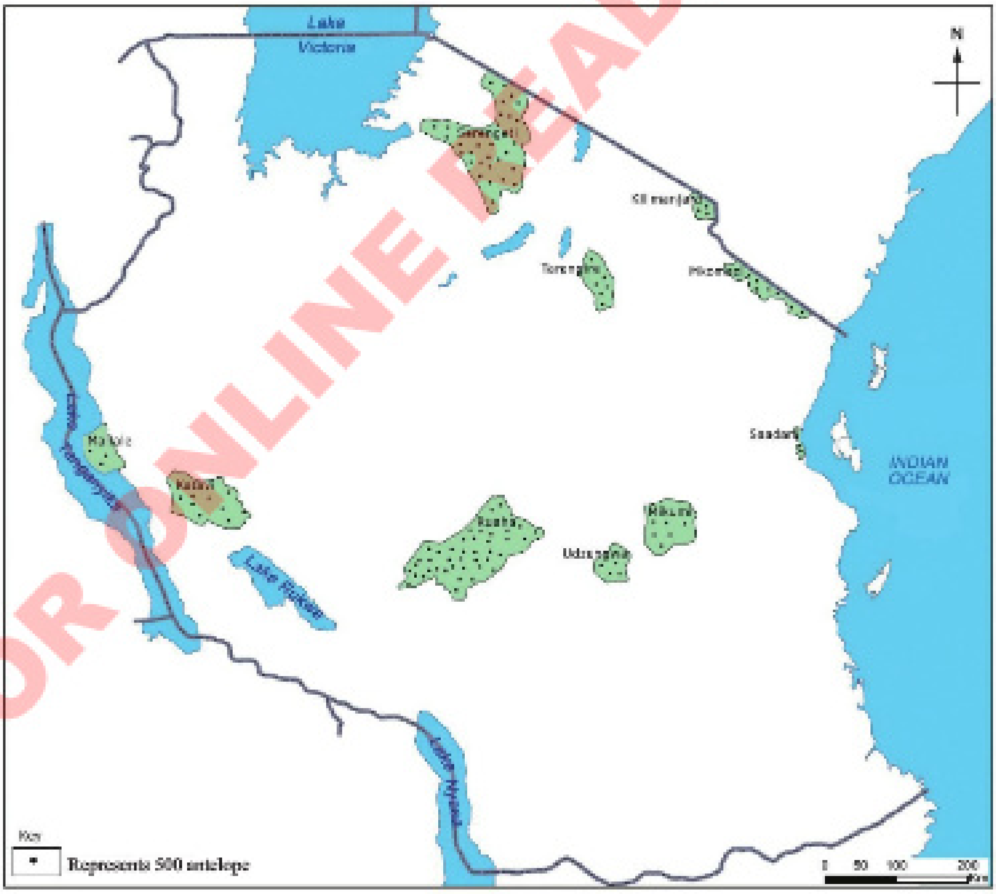


Figure 3.31: *Distribution of antelopes in the selected gazetted national parks in Tanzania by 2019*

The advantages and disadvantages of dot maps in geographical research

Dot maps are simple to use since the lower the dot value, the more accurate the picture of distribution and value. The map can be interpreted quantitatively, that is, the number of units within each boundary can be counted. The value and location of several items can be shown on the same map by using different colours and symbols. Examples of items may include goats and donkeys different ethnic groups and a range of crops or minerals. Similarly, calculation and drawing may be fairly easy and the result is graphically pleasing. It is also simple to delete the dots used on the map.

However, the dot maps have some limitations such as the possibility of faults in construction. If dots merging is not apparent until the map is nearly completed, re-calculation and redrawing of the map will be necessary. If no topographical information is available, evenly spaced dots will give a false impression, like the chrolopleth. Moreover, with large dot value, spatial distribution cannot be accurately shown, except for the general distribution. Dots must be placed in the gravitational centre of the actual distribution. Furthermore, the approximation of decimals, for example 6.51 ≈ 7, distorts numbers of the total population. Finally, the method is time consuming due to scale calculation and drawing of the sketch map.

Isoline map

Isoline map is also known as *isopleth map*. It is one of the popular methods of geographical data representation. Isoline stands for line joining places or points with equal value. The term isoline is interchangeably used with isarithm and isometric lines. The word isoline is derived from the Greek word *isos,* meaning equal. Table 3.64 shows phenomena on a map which can be represented by isolines.

Table 3.64: *Phenomena on a map which can be represented by isolines*

S/N	Types of line	Variable represented
i	Contours	Elevation
ii	Isotherm	Temperature
iii	Isobars	Pressure
iv	Isohyet	Rainfall
v	Isoneph	Cloudiness
vi	Isobath	Ocean depths
vii	Isohalines	Salinity
viii	Isohel	Sunshine
ix	Isohume	Humidity

Procedures

The following are precedures for constructing isoline map.

(i) Choose a suitable isoline interval; for example, an intervals of 2 °C for temperature data in Figure 3.32;

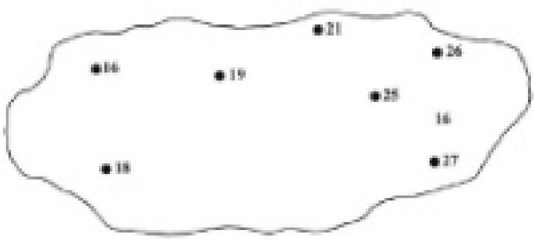


Figure 3.32: *The map showing temperature in °C at different parts in hypothetical place X.*

(ii) Determine the values to be connected by isolines, in this case 16 °C, 18 °C, 20 °C, 22 °C, 24 °C and 26 °C;

(iii) Determine the position where isolines of 16 °C, 18°C, 20 °C, 22 °C, 24 °C and 26 °C passes between points shown on Figure 3.32 through interpolation. For example, isoline 18 °C passes between point 16 and 18 as shown in Figure 3.33.

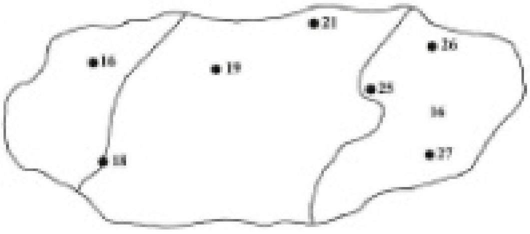


Figure 3.33: *Isoline showing temperature in °C at different parts in hypothetical place X*

(iv) Then, you can shade the space between isolines to show areas with low, moderate and high temperature as shown in Figure 3.34.

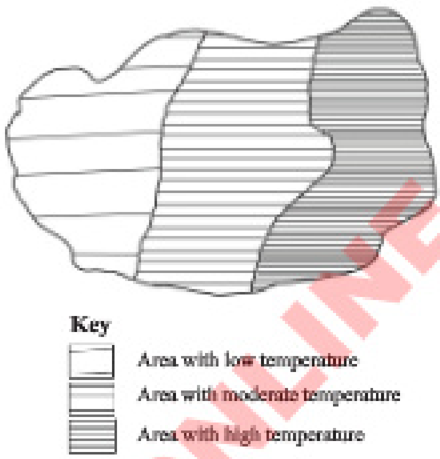


Figure 3.34: *Shaded isoline showing temperature in °C at different parts in hypothetical place X*

Advantages and disadvantages of isoline maps in geographical research

Isoline maps have both merits and limitations. The main benefits with isoline map is that, the value can be obtained at any point on the map. Where points are not on isolines, their values can be obtained by interpolation. The interval between each isoline suggests gradual and abrupt change, hence shading must be well graded to maintain this aspect. Furthermore, isolines can be combined with other data such as population and crop distribution and related to isohyet (rainfall map). Despite this, isoline map has some limitations. These include the subjectivity in interpolation of point value and reliance on the judgment of the individual cartographer.

Some data distributions can be interpreted in different ways, thus can result into duplication of isoline maps. Furthermore, in a situation with a large number of data, points can consume more time to accomplish the process of drawing isoline maps. Additionally, lines drawn for one feature may automatically interfere with other linear features on a map. In short, it is difficult to represent more than one feature in a single map.

Choropleth map

A choropleth map is derived from the Greek word *choros* meaning area or region and *plethos* meaning multitude. It is a type of a thematic map which is proportionally shaded, coloured, patterned or striped to indicate the pre-defined areas to a geographical variable represented on a map as an aggregate summary of a geographical characteristic within an area as shown in Figure 3.35. Furthermore, Choropleth map is a map in which population densities of different areas are shaded in different colours or patterns. Choropleth map is also known as the real density map.

Procedures

The following are procedures for a construction of choropleth map:

(i) Classify data into few classes for easy presentation;

(ii) For each class, identify areas or regions within it; and

(iii) Shade each region or area depending on the class it belongs to. Shading density should increase from lower class to higher class.

Example: Using Table 3.65 construct a choropleth map for population density in selected regions in Tanzania.

Table 3.65: *Population density in selected regions in Tanzania*

Region	Population	Area in sq km	Density
Mbeya	1 250 605	87 567	14.28
Njombe	1 030 805	38 906	26.49
Arusha	1 355 685	84 567	16
Dodoma	1 020 815	47 311	21.57
Kigoma	855 807	45 066	18.99
Rukwa	1 000 825	35 705	28

Source: *Tanzania census survey (2012)*

Solution

(i) Classify population density into four classes as follows:

Geometric progression classes

11 – 15.9 Mbeya

16 – 20.9 Arusha, Kigoma

21 – 25.9 Dodoma

26 – 30.9 Njombe, Rukwa

(ii) Identify regions falling within each class as shown in (i); and

(iii) Shade each region with density increasing from lower class to higher class as shown in Figure 3.35.

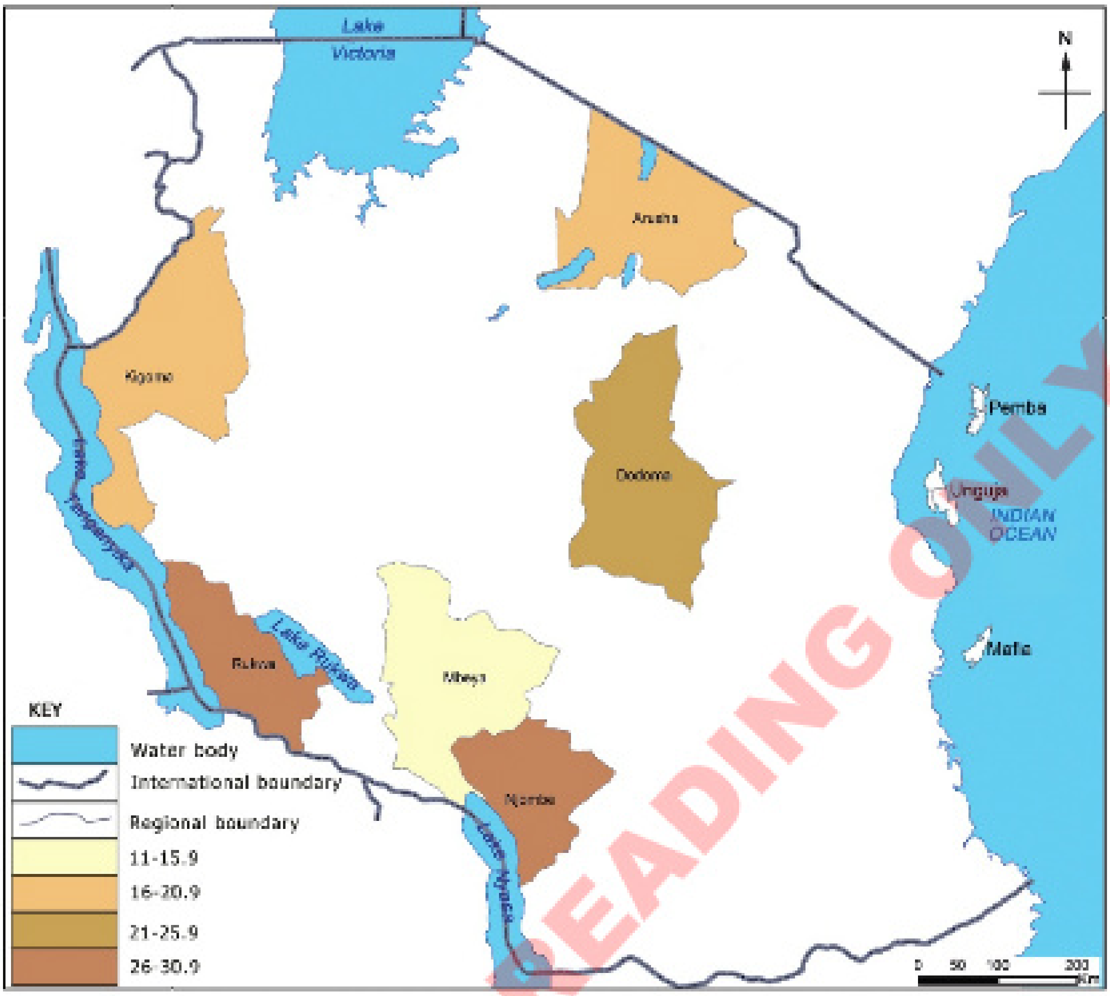


Figure 3.35: *Population density in selected regions of Tanzania.*

Advantages and disadvantages of choropleth maps in geographical research

Basically, choropleth maps are useful in a number of ways. The major ones include providing a good visual impression of the elements studied; easy to comparison of population densities of each unit, easy to interpret with the aid of key and simple to draw when a map and a table have been provided. Moreover, choropleth map can accommodate any scale.

Conversely, some limitations of the choropleth maps include giving a wrong impression that density changes suddenly at boundaries in a given map. Furthermore, variations of the density within each boundary are not shown, hence giving an impression that there is uniform density within each administrative unit. Shading may obscure/hide other features. Additionally, drawing of the choropleth maps is tiresome and time consuming, particularly shading of large data.

Flowline map

Flowline map, also known as *flow chart*, is a diagrammatical presentation of the movement of goods or number of vehicles, people and cattle from one place to another. It may show the movement of goods from production area to the market or point of export. The volume of flow is shown by a line, whereby the width of the flow is an important factor which varies proportionally with the varying number of goods or people traveling along the given routes. Also, width may be determined by the types and frequency of traffic (by road, rail, air or water) of the migratory movement of people, or stock, the paths of cyclone or ocean currents, the direction, quantity or characteristics of exports or imports and many other geographical phenomena involving movement.

Procedures

The following are procedures for constructing a flowline map:

(i) Choose a scale which is appropriate to the data given, usually, the smallest width to represent small volume of flow;

(ii) Using the scale, calculate line width to represent each volume of flow;

(iii) In drawing the flowline on the base map, it is not necessary to follow all the twistings and windings of a road or railway;

(iv) The meeting place of various flow line (for example, a market town, bus station, port of import or export, collecting centre and so on), can be shown by various methods, the easiest method being to draw a shaped nucleus. It should be noted that the nucleus may develop but the interest is in the movement of commodities and not representation of meeting places; and

(v) Write the title and key.

Example

Using data in Table 3.66, draw a flowline map.

Table 3.66: *Movement of rice in tonnes from Morogoro to other regions in Tanzania*

Region	Tonnes of rice
Iringa	12000
Dodoma	18000
Tanga	8000
Dar es Salaam	20000

Solution

(i) A line width of 1 mm is chosen to represent the volume flow of 8 000 tonnes;

(ii) Determine the line width to represent different volume by dividing volume by 8 000 tonnes as shown in Table 3.67.

Table 3.67: *Line width representing movement of rice in tonnes from Morogoro to other regions in Tanzania.*

Region	Tonnes rice exported	Line width
Iringa	12000	12000 ÷ 8000 = 1.5 mm
Dodoma	18000	18000 ÷ 8000 = 2.3 mm
Tanga	8000	8000 ÷ 8000 = 1 mm
Dar es Salaam	20000	20000 ÷ 8000 = 2.5 mm

Note: Absolute scale: 1mm to 8000

(iii) Draw flow lines of respective width to connect Morogoro and the four regions as shown in Figure 3.36;

(iv) Show legend.

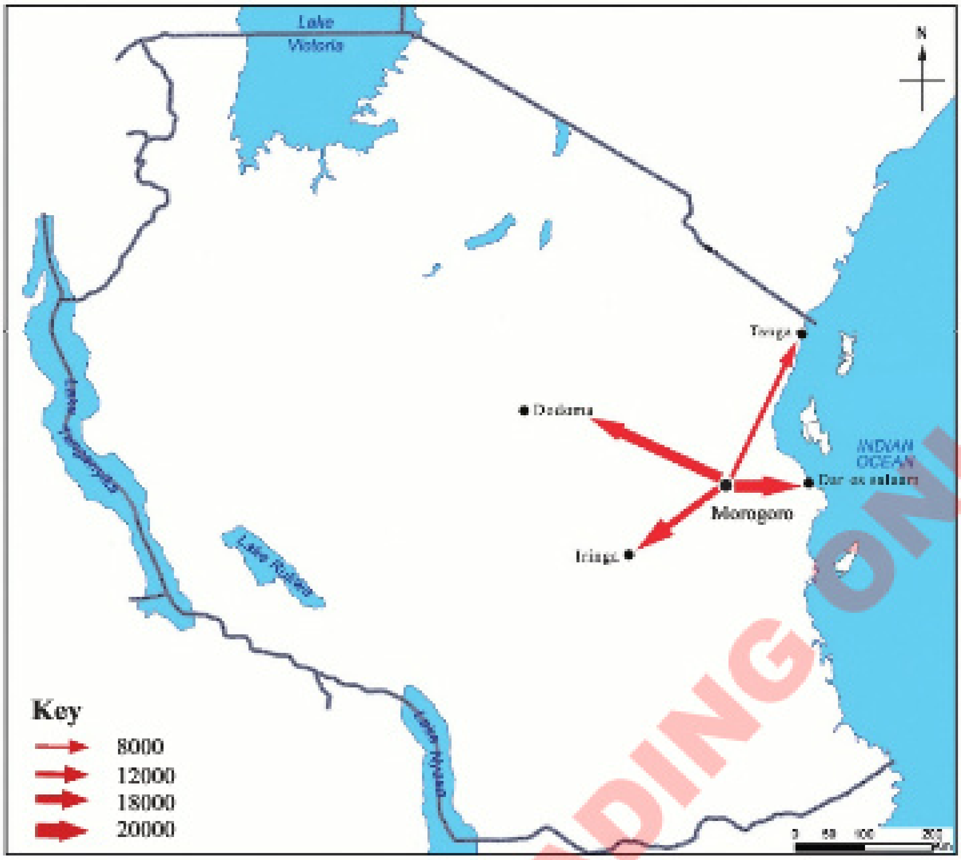


Figure 3.36: *Flowline map showing movement of rice in tonnes from Morogoro to other regions in Tanzania*

Advantages and disadvantages of flowline maps in geographical research

The flowline maps are widely useful as flow data methods of presentation and interpretation. The flowline maps can clearly and insightfully give clue on the problems that are likely to hinder movement, for example, traffic congestion. Flowline maps are very versatile and can show two traffic and various methods of transport. Additionally, the method of construction is fairly easy once the scale has been decided. However, the flowline maps have some limitations such as very low volumes represented by a non-scaled line. Moreover, log or square root flowlines lose their direction proportions and the reader has to use the key frequently. Furthermore, the wide variation between the highest and the lowest volume of data makes the scale difficult to assess.

Activity 3.6

Choose any region in Tanzania, search its map showing districts and collect the respective population data then, prepare:

(a) Dot map
(b) Choropleths map

Geographical research and computer science

After studying various methods of data analysis and presentation, it is important to shed light on the existing sophisticated means of geographical data management.

The growing wave of science and technology has attracted the geographers in integrating the field of computer and information technology in geography. Though not covered extensively in this book, it is important to understand how the era of computer science has simplified management of numerical data. It is undeniable truth that to date, computer can be used in the recording and storing of a massive numerical data collected from the field and summarising it to make meaningful information for interpretation and reporting.

The modern electronic computer can be used as a tool in performing a number of geographical calculations within a short time. Geographers can make use of computer in a number of ways including recording, analysing, summarising data and commanding the computer software to generate figures and tables based on recorded data, thus simplifying interpretation. The increasing knowledge and skills on computer has enabled drawing of computer-based maps indicating distributions of data such as temperature, rainfall and population in a given location or area.

Currently, geographers are developing interests in understanding computer software and programmes that are vital in managing statistical data. Some useful computer software and programmes that can be employed in data analysis include Microsoft Excel and Statistical Product and Service Solution (SPSS) which were known for the past several decades. The desired statistical output of data from the computer relies on the good data entry for analyses and the choice of the appropriate output command.

Interpretation of results

The purpose of the research is to derive certain conclusions, from the analysed and presented geographical results. The act of making sense of geographical data that has been gathered, examined, and presented is referred to as *interpretation*. The data pattern, interpretation, and comprehensive explanation of the outcomes are examined before drawing a conclusion.

Interpretation and generalizations of geographical information

In this stage, the researcher finds out whether the facts from the field support the formulated hypothesis. This means that research results obtained from the field are used to make decisions regardless of whether they support the hypothesis or not. On testing the hypothesis, two possible outcomes are expected, that is, the findings may support or not support the hypothesis. In case the findings do not support the hypothesis, new hypotheses can be formulated, restated basing on the findings and re-tested.

If the hypothesis is tested and supported several times, it can increase confidence to the researcher in arriving to generalisation and building a theory. As a matter of fact, the real value of research lies in its ability to arrive at certain generalizations. A researcher who has no hypothesis to test might seek to explain the findings on the basis of some relevant theory or theories that underpinned the study. Finally, the researcher has to prepare the report of the findings.

Revision exercise 3

1. The following table indicates fish production (mega tonnes) in Tanzania from 2005 to 2016.

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Fish production (Mega tonnes)	625	715	806	865	936	952	959	972	2990	3000	3118	3840

   (a) Draw a divergent line and bar graphs for these data.
   (b) Interpret the resultant graphs.
   (c) Identify alternative methods which may be used to present the data from the given table.

2. The following table shows livestock production for the five years from 2012 / 2013 to 2017 / 2018.

Livestock Product	Livestock production per annum in tonnes					
	2012/2013	2013/2014	2014/2015	2015/2016	2016/2017	2017/2018
Beef	20 587	40 167	9 226	22 899	32 524	7 403
Chevron	12 062	10 153	4 631	5 918	8 838	2 326
Mutton	1 643	1 831	1 309	1 168	1 718	374
Chicken	272	280	298	325	319	462

Source: *Dodoma region investment guide (2019)*

   (a) Draw a compound line and bar graphs.
   (b) Interpret the results.

3. The following table shows hypothetical annual rainfall (mm) from the selected regions in Tanzania for the year 2016.

S/N	Station	Rainfall in mm
1	Kagera	1452.9
2	Dar es Salaam	782.9
3	Mwanza	1039.3
4	Mara	627.2
5	Kilimanjaro	492.5
6	Morogoro	587.6

   (a) Draw multiple line graphs and interpret the results.
   (b) Find total rainfall in the regions and construct a bar chart.
   (c) Describe the results.

4. The following table shows forest plantations (ha) established by the Tanzania Forest Services (TFS) between 2014 and 2017.

S/N	Plantation name	Total area (ha)
1	Morogoro (Morogoro)	37
2	North Ruvu (Pwani)	523
3	Chato Biharamulo (Geita)	440
4	Mpepo (Ruvuma)	395
5	Iyondo Mswima (Songwe)	200
6	Korogwe (Tanga)	220
7	Buhigwe (Kigoma)	60

Source: *Tanzania Forest Services (2017)*

(a) Construct the following from the given data:
- (i) Simple divided rectangle
- (ii) Simple divided circle
- (iii) Simple divided semicircle
- (iv) Proportional circles

(b) Interpret each of the results in (a) (i) - (iii)

5. The following table shows temperature in degree celsius and rainfall in millimetre for a hypothetical meteorological station in 2007.

Months	J	F	M	A	M	J	J	A	S	O	N	D
Temp(°C)	22	23	29	24	25	26	28	27	25	25	24	20
Rainfall (mm)	250	250	300	350	360	380	370	150	200	250	300	350

(a) Present the data by using:
- (i) Polar chart
- (ii) Climography

(b) With reasons, suggest the climatic region of the station.
(c) In which hemisphere is the station located?
(d) Find the median temperature.

6. The following data shows human population in the hypothetical regions.

Region	Population
Songambele	830 000
Cheju	310 000
Makikisa	570 000
Guben	180 000
Choro	270 000

(a) Present the data using a dot map.
(b) Comment on the distribution of the population.

7. (a) Using the data in the table, draw a flowline map to show the movement of vehicles between Mwanza and Dar es salaam.

From	To	Vehicles	From	To	Vehicle
Mwanza	Tabora	1 500	Dar es salaam	Morogoro	2 500
Tabora	Dodoma	2 000	Morogoro	Dodoma	2 000
Dodoma	Morogoro	2 400	Dodoma	Tabora	1 200
Morogoro	Dar es salaam	3 000			

(i) What are the disadvantages of the method used in (a)?
(ii) Comment on the statistical map you have drawn in (a).

(b) Describe the stages employed in constructing dot maps.
(c) What are the limitations of dot maps?

8. The following table shows students in class 'Z'.

Class interval	Frequency
0 – 4	2
5 – 9	11
10 – 14	37
15 – 19	54
20 – 24	28
25 – 29	9
30 – 34	1
35 – 39	3

(a) Find the range.
(b) Calculate the standard deviation.
(c) What are the advantages and disadvantages of range in a given geographical data?

9. The following table shows the average number of people per tractor and the % population in agriculture by country.

Country	% of population in agriculture	Number of people per tractor
Kenya	76	3 006
Korea	45	1 900
China	56	1 247
Egypt	49	1 117
Sudan	34	142
Burma	12	120
Ghana	04	38

(a) Draw a pie chart to show the number of people per tractor per country.
(b) Comment on the pie chart you have drawn in (a) above.

10. The following table shows cash crops production in '000 tonnes in the hypothetical data country.

Year	Types of cash crops		
	Rice	Maize	Wheat
2021	2 000	1 000	3 000
2020	1 500	1 300	2 000
2019	1 200	1 000	1 000

(a) Represent the data above using a compound bar graph.

(b) Comment on the trend of production from the graph.

(c) Explain the relevance of the compound bar graph.

11. With examples, explain how measures of central tendency and measures of dispersion can be used in our daily activities.

12. The following table shows the natural gas production for the two sites in Tanzania from 2012 to 2017.

Year	Gas field in million cubic feet (MCFT)	
	Songosongo	Mnazi Bay
2012	36 233.01	672.14
2013	35 217.41	712.02
2014	33 062. 00	784.69
2015	31 384.00	5 799.41
2016	29 747.48	15 792.28
2017	29 497.32	17 960.30

Source: Tanzania Petroleum Development Cooperation (TPDC)

(a) Calculate the standard deviation of the gas product at each site.

(b) Compare the standard deviations between the two sites and explain the variation of standard deviations (if any).

(c) Based on the comparison observed in question 12 (b), what recommendations could you provide to TPDC?

13. Range is always regarded as the least, useless measure of central tendency. Substantiate on the basis of statistical geography.

14. As a geographer, explain the relevancy of mode and mean in daily life.

15. Read the following material in a group of at least five students: Geographical data processing, analysis, presentation, and interpretation of results based on the available resources (books, the internet, and libraries) and then do the following:

(a) Summarize the following concepts:
   (ii) Geographical data processing
   (iii) Geographical data analysis
   (iv) Presentation of results
   (v) Interpretation of results

(b) Explain the relationship between presentation and interpretation of results and research conclusions.

(c) Explain the significance of geographical data processing in further research stages.

(d) Explain what will happen if the researcher interprets the research results incorrectly.

Chapter
Four

Techniques of photograph interpretation

Introduction

Photography interpretation skills are important in our lives. In this chapter, you will learn about the concept of photograph, images, satellite images and photograph interpretation. You will also learn the techniques of photograph interpretation. The competences developed will enable you to interpret photographs and images.

Think about

Decoding visual information to discover patterns of geographical features and their significance to life

Basic concepts of photograph interpretation

Activity 4.1

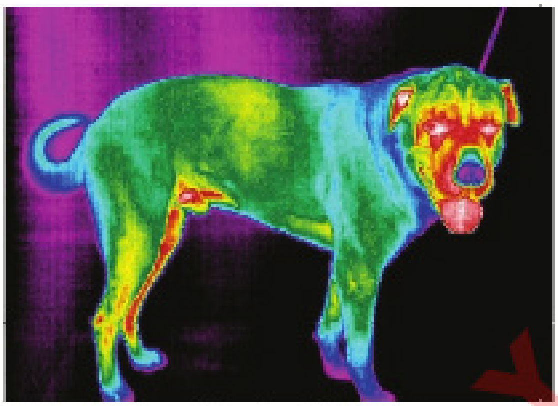
(a) Collect photographs and images from online and other sources.

(b) Study the collected photographs and images then write down their key features, indicating their similarities and differences.

Photographs are images which represent an object. Although the term *image* refers to any pictorial representation of a feature or object, a photograph must be an image. All images represent some aspects of objects. Images are categorised based on the wavelength of electromagnetic radiation. Names like X-ray pictures, infrared images, radar pictures and photographs (Figure 4.1) are commonly used for differentiation of the images based on a different range of wavelengths. They are recorded by cameras or sensors within any wavelength. Therefore, photograph is both a *picture* and an *image,* but not all images are photographs.

Another distinction between photographs and images is based on sensors. All cameras detect a particular wavelength and represent it in their own way. A camera measures the visible part of electromagnetic spectrum and represents the wavelength as a photograph. Yet, there are x-ray sensors which detect x-ray part of spectrum and produces x-ray images. Therefore, all cameras are sensors but not all sensors are cameras.

(a) Photograph



(b) Infrared image

(c) X-Ray

Figure 4.1 *Categories of images under different wavelengths*

The concept of satellite and image

Satellites are just man-made car-like carriers of sensors. They are platforms on which photographic and imaging sensors are mounted. They function like human hands or camera stands we are used to. They are not sensors, but they just hold sensors intact and provide support to sensors. There are various satellites in the space, developed and launched by different nations and companies for different purposes (Figure 4.2).

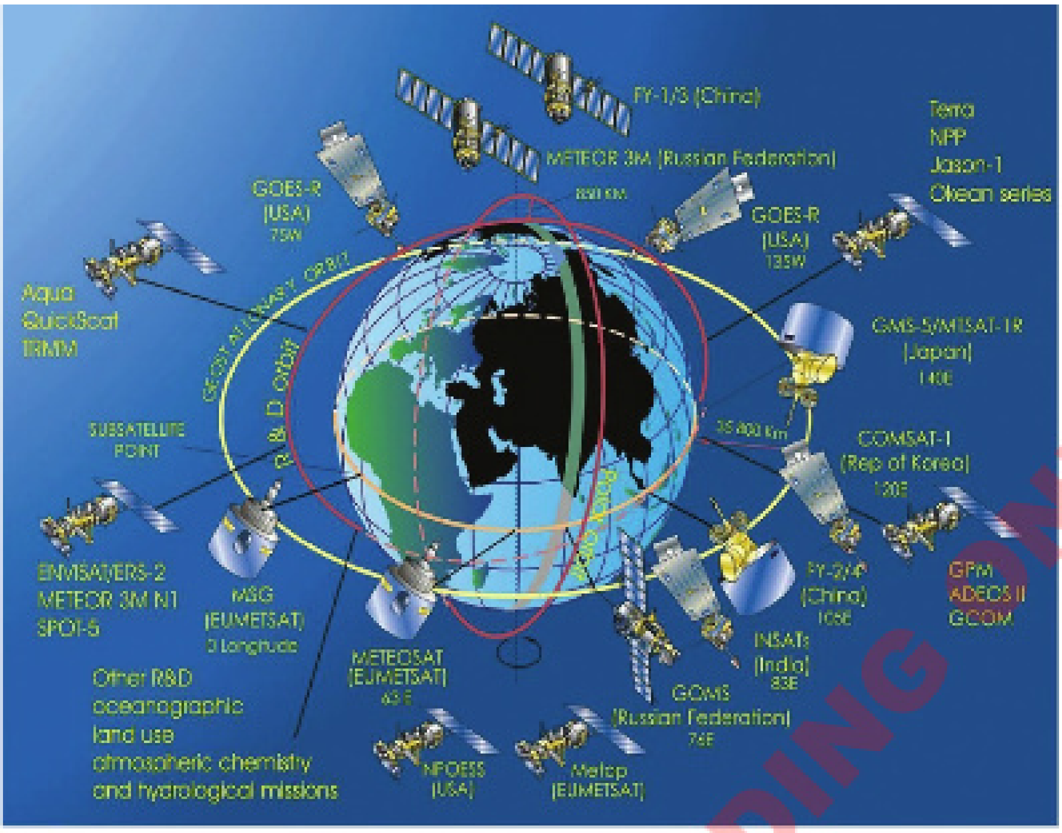


Figure 4.2: *Different satellites and their orbits*

These platforms carry sensors (including cameras) which collect images for different purposes. Satellite sensors have supplied billions of free and commercial images which can easily be downloaded and used for all other photographic applications. Some sensors do not produce photograph-like-images, they rather provide reflective and emission signatures of the world's resources and conditions.

Every earth's object has its unique reflection and/or emission signature. This means that the reflective properties of vegetation differ from those of water and those of human bodies are different from those of soil. Therefore, satellites provide images which can require different of reading and interpretation techniques and skills.

Satellites are placed on a particular path called an *orbit*. There are three types of satellite orbits: sun-synchronous satellite (placed at about 500 km - 900 km); geostationary satellites also called geosynchronous (placed at about 36 000 km) and low Earth orbits. Geostationary satellites carry sensors for meteorological and telecommunication monitoring. Sensors at sun synchronous satellite are generally used for remote sensing studies. Low Earth orbiting (LEO) satellites can be used for spying. The satellites detect and capture mass of data in a very wide range of wavelengths including, but not limited to, visible (Figure 4.3), near infrared and mid infrared.

Generally, the information acquisition process by a recording device that is not in physical contact with the object under study is called *remote sensing*.

Figure 4.3: *Satellite image*

Satellite sensors produce a multitude of images in different wavelengths which can be called photographs to be interpreted and used for our daily lives. They provide images on meteorology, oceanography, biodiversity conservation, forestry and regional planning. They provide images on which much of decision regarding land use planning, management and mapping can be categorised on the bases of their imaging systems.

Contribution of satellite images to geographers and the community

Satellite images provide meteorological data on different aspects including cloud cover, rainfall, hurricanes and oceans tides which can be used for meteorological broadcast and disaster prediction and control. Satellite imagery also provides information regarding wildfires, volcanoes, torrents and that can help to minimise negative impacts on people. Satellite's ability to produce massive images has helped land use planners, map makers, oceanographers and even agriculturalists to utilize them for the betterment of human lives. Satellites supply data used for updating our existing maps.

Satellites enable the operations of mobile phones, radio stations and television broadcasts. They enable tracking vehicles and people and simplify navigation systems necessary for geotechnologies and geographic information systems.

The difference between aerial photographs (which is the broader term representing photograph taken from the air) and satellite images is summarised in Table 4.1.

Table 4.1: *Difference between aerial photographs and satellite images*

Satellite images	Aerial photographs
They cover a large area, approximately 185 x 185 km^2. This is due to the fact that they are situated higher than air crafts.	They cover a small area, approximately 23 x 23 km^2.
Are based on visible and invisible parts of electromagnetic spectrum.	Can record only the visible part of electromagnetic spectrum.
Difficult to interpret due to low spatial and high spectral resolution (wide range of electromagnetic spectrum).	Easy to interpret thanks to high spatial resolution and small range of spectral resolution.
Are taken throughout the year. Thus, it is easy to record and detect seasonal changes in the year as satellite captures different images within a few days.	It is impossible to have a repetitive coverage of the whole world.
They show fewer details due to a small scale, and low spatial resolution.	They show more details thanks to a large scale and high spatial resolution.

Exercise 4.1

1. All photographs are images but not all images are photographs. Justify.
2. Account for the relevancy of photographs in social and economic activities.
3. Describe how the satellites link to our daily lives.

Photograph interpretation

Interpretation entails giving analysis to an image. Everyone to a certain extent, is a photo-interpreter. Interpretation, involves observing objects to recognise and analyse their shapes, alignments and relationship to the environment. Photograph interpretation is a critical examination of the presented photographic object to identify and then judge their significance and meaning.

Photograph interpretation is an interplay of several objects and interpreter's variables. Variables which can also be considered as the principles to objective interpretation include prior knowledge of the captured area and understanding of the subject matter. Key variables for photo interpretation include shapes, sizes, tone, organisation, shadow, texture, among others. During photo interpretation, all variables are applied simultaneously to deduce or induce information. For example, looking in Figure 4.4, one recognises that the objects in the photo are lions and not elephants or hyena. This recognition is made by looking at the shape, size, own experience, tone and texture variables such as shadows, shadow point, area of maximum shadow, the effects of sun's altitude and those of the sunlight.

Figure 4.4: *Lions*

Although a shadow is a pertinent element to help photograph interpretation, it can obstruct a feature from identification. A shadow can cover objects and cause difficulty in recognition. There are times when the relief displacement of an object matches exactly with the shadow; thus, it cannot be seen. The point where the relief displacement of objects exactly matches with the shadows such that no shadow is visible is termed as *no-shadow point or Hot spot* (Figure 4.5).

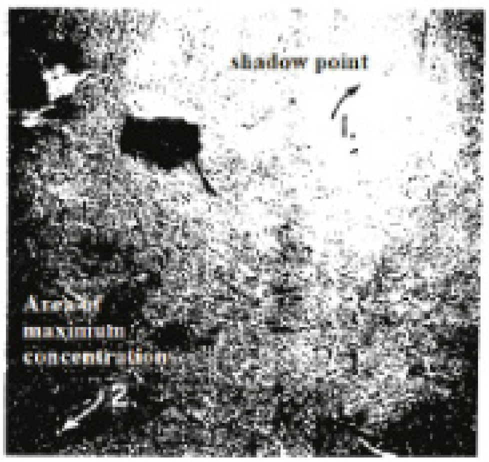


Figure 4.5: *Shadow point*

Also, there are cases where too much brightness hinder identification of features in a photograph. Depending on the time when the photograph was taken, a camera records the greatest proportion of shadow accentuated by glare in areas which are away from the sun. The quality of one's interpretation can be affected. On recording or taking picture, the place where the photographer is located determines the shape, size, tone, organization and type of the photograph. Photographs can be grouped into *ground photographs*, *aerial photographs* and *satellite image photographs*.

Ground photographs, as the name suggests, are camera pictures taken horizontally or obliquely from the ground level. They record objects with a camera carried by a person or vehicle which is on the ground. Photographs under this category give a horizontal view of the object recorded. Ground photographs are further categorise into ground horizontal, ground close-up and ground oblique photographs.

Ground horizontal photograph

Ground horizontal photographs are taken from the ground perspectives when the axis of the camera is placed horizontally towards the object. Ground horizontal photograph is the most common type of photograph. The main characteristics of all ground horizontal photographs is that they clearly show side or front view of the objects (Figure 4.6).

Figure 4.6: *Ground horizontal photograph*

Ground close-up photograph

Ground close-up photographs also known as ground view photographs are camera pictures taken closer to the object. They are characterized by large objects at fore ground (Figure 4.7). A ground close-up photograph shows objects in a progressively decreasing scale size from the camera tilt angle. The photograph shows objects whose sizes decrease from the foreground to the back ground. The main objects to be shown are somehow apart from the photographer. Some of the photograph parts include small horizon in their background. The photographs are easily divided into three main parts, namely the *fore ground, middle ground* and *back ground*. The picture is always clear and does not show the top view.

Figure 4.7: *Ground close-up photograph*

Ground oblique photograph

Ground oblique photographs are taken from up-heaved land. They can be taken from house roofs, hills or mountains at an angle between 30° and 60°. The pictures can easily be divided into the foreground, middle ground and background. The amount of horizon at the background depends on the camera's tilt angle. Objects from the foreground decrease their sizes towards the background. The top part of the object is partly seen relative to the camera's angle. This means that, photographs taken at an acute angle greater than 50° have their top seen than those taken at 50° (Figure 4.8).

Figure 4.8: *Ground oblique photograph*

Advantages of ground oblique photographs

Ground oblique photographs have been serving an important role in social-economic development. They provide relevant landscape data timely and at the required place. Also, they supplement data which cannot be collected by high geotechnologies such as the intensity and extent of flooding or the effect of locusts in a recognisable area on global geotechnologies. Furthermore, oblique photographs can aid field sketching as features are large and can be clearly seen. However, their inability to cover a large area makes it unsuitable for interpreting features on a large area. They can easily be interpreted to provide a conclusion which cannot be generalized as the area covered may not be representative of the whole area under study. However, compared to the ground close-up, ground oblique photographs represent more features. They provide more information that could support land use planning. The relief of a given landscape is much clearer than ground horizontal photographs. It shows a top view and side of an object. This is important in producing small sketch maps in the field.

Disadvantages of ground oblique photographs

Ground oblique photographs tend to distort uniformity of the photo since the scale decreases from the foreground to the background. It is difficult to determine the scale of the photograph unless the photographer knows the size of an object. Again, photograph cannot be used for a large area map production. Another constraint is that the horizon cannot be seen properly. In this regard, it is important to note that the main feature of oblique photographs is that they show top and side or front view of the objects.

Parts of a photograph

A number of skills apply in the process of interpreting images. For example, you may see a hygrophyte or xerophyte plant on a photo and you want to describe it. In that case, you are required to section the photograph. A photograph can be sectioned horizontally into the *foreground, middle ground* and the *background* as shown in Figure 4.14. At the foreground, features appear big and clear. The middle ground is the area in the middle distance away from the camera. At this section, the size of the objects appears relatively small but moderately clear. The area farther away from the camera with tall trees including the horizons is called the background. At this part, features appear to be small and not clear.

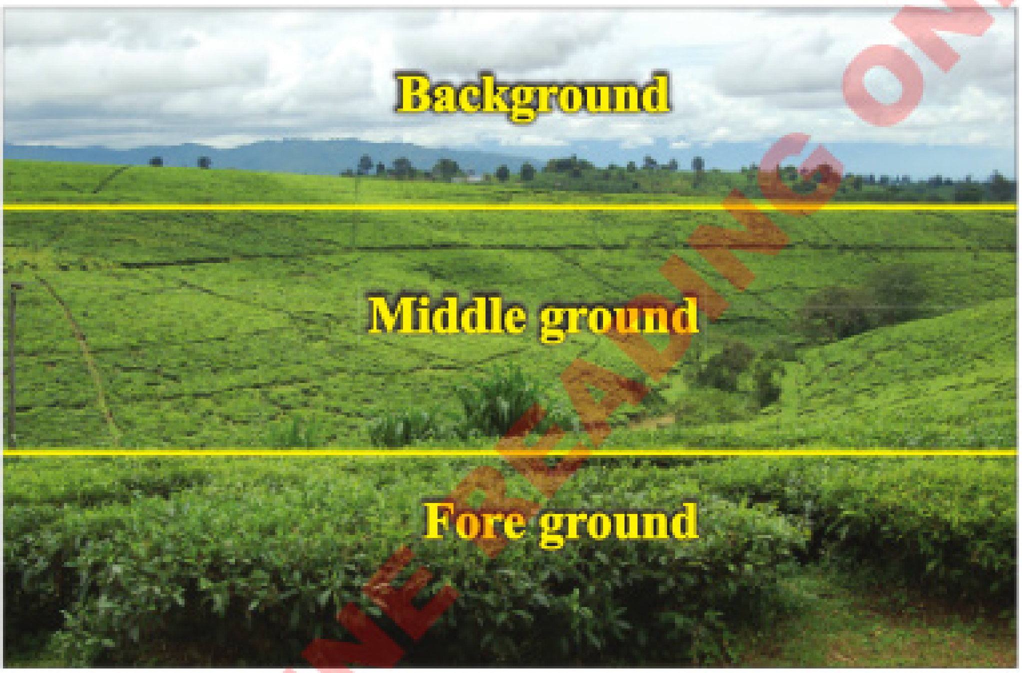


Figure 4.14: *Location of parts of photograph horizontally*

As the need may arise, you can divide a photograph further into three equal vertical parts: left, centre and right. When describing a side of a particular object, you can then refer them as located to the *left at the foreground or background* and to the *right at the foreground* in Figure 4.15. The centre or background term should be used to address the object's location relative to other objects in the photograph. Words like top or bottom, North or East are not recommended in photograph interpretation.

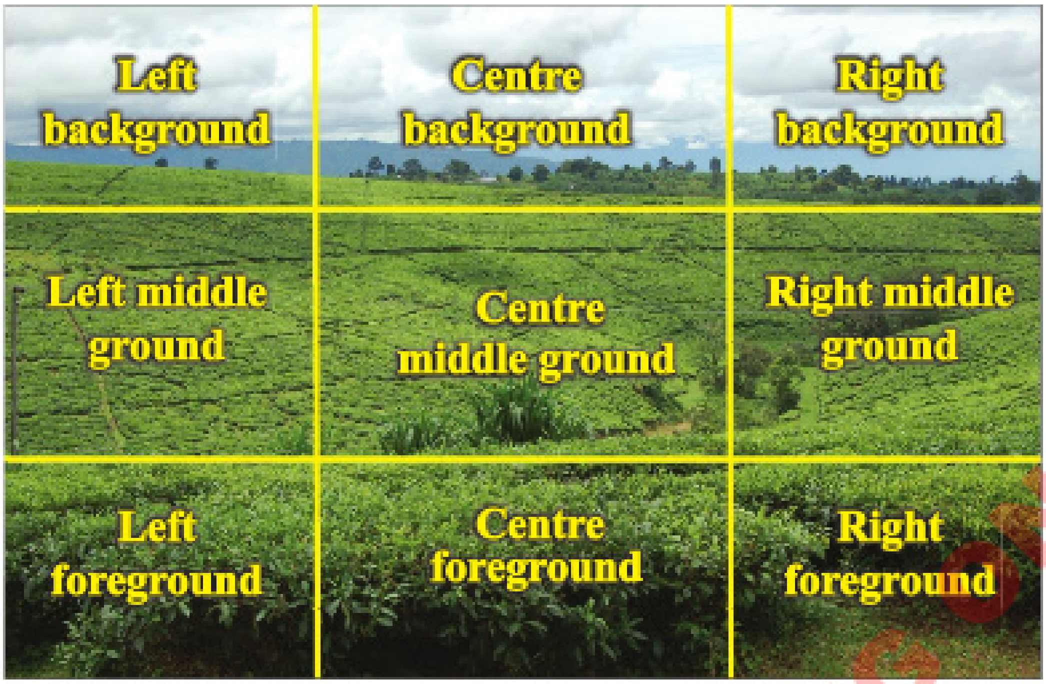


Figure 4.15: *Location of parts of a photograph commonly used in interpretation*

Activity 4.2

1. Carefully study the following photograph and answer the questions that follow.

Source: https://www.derrystrabane.com/strathfoylegreenway

(a) What is the type of this photograph?

(b) Section the photograph into nine parts and mention the features found in each part.

(c) What would be the usefulness of having such a photograph?

(d) What social activities could be taking place in the area?

Techniques for interpreting ground and oblique photographs

The basic hints or techniques for ground photograph analysis are as follows:

(a) Identify parts, sections or positions of photograph that is the fore, middle and background of photograph and make a note of important features shown;

(b) Read the caption and look at the position of the feature and draw a simple sketch map of the area. If the objects decrease from left to right hand side, they indicate that the photographer was on the left side. If the objects decrease from right hand side, it indicate that the photographer was on the right hand side. If the objects decrease from the fore to the background of the photo, they indicate that the photographer was in front of the objects;

(c) Lay a piece of tracing paper over the photograph and draw a trace diagram showing more important features;

(d) Write short descriptions of the features shown in the photograph; and

(e) Describe the processes which have led to the formation of any landforms and landscapes in the observed photograph.

Several aspects need to be considered in analysing photographs. One of the aspects are the effects of perspective objects where objects appear much larger than those further away. Each picture has a foreground, middle and background section. The clarity of the photograph must also be considered. This varies due to atmospheric conditions and quality of the film. The caption, if provided, should be considered carefully. The time of day at which the photograph was taken is important as long evening may obscure important details.

Activity 4.3

1. Read materials from various sources, then describe the relevance of various categories of ground photographs in planning.
2. Search for a ground oblique photograph and identify features.

Aerial photographs

Aerial photographs is the type of photographs taken from above. You should not be confused with the phrases *Aerial photography* and *Aerial photograph*. The latter is a product and end result of aerial photography. Since its invention in 1830s, aerial photography has been the most effective technique used for map making, showing boundary location, determining road alignment and vegetation delineation, among many other activities. This is the essence you should learn about aerial photographs. Aerial photographs are pictorial representations captured by sensors mounted on flying planes such as kites, aircraft, helicopters and drones (Figure 4.9). Formally, helicopters and airplanes were highly valuable, though recently, drones are outpacing them.

Figure 4.9: *Drone*

Classification of aerial photograph

Aerial photographs can be categorised on the basis of several criteria as *orientation of camera axis* (such as vertical photograph and oblique photograph); angular coverage and emulsion type such as panchromatic black and white photographs, colour photographs, infrared, black and white photographs and false colour composite photographs. This section present the types of aerial photographs based on camera axis.

Types of aerial photographs

Aerial photographs can be categorised into vertical aerial photographs and oblique aerial photographs (Figure 4.10)

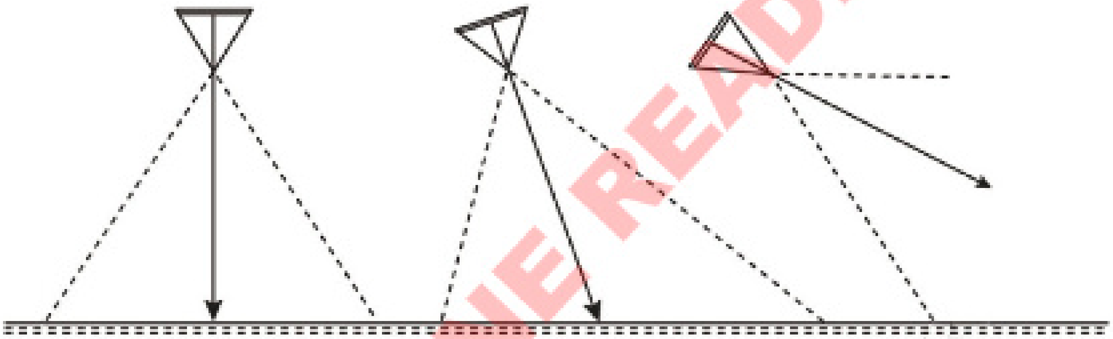


Figure 4.10: *How different types of aerial photographs are taken*

Vertical aerial photograph

Vertical aerial photographs are taken by a camera with its axis perfectly or nearly vertical. They are characterised by showing only the top view of objects than side views (Figure 4.11). The turbulences that shake airplanes and drones can distort the verticality. Other vertical aerial photographs are the pictures taken by Satellites at a very high altitude.

Figure 4.11: *(a) Flying aircraft taking a vertical aerial photograph*

Figure 4.11: *(b) Vertical aerial photograph*

Vertical aerial photographs cover a relatively large area compared to any other type of ground photographs. Though its scale is almost the same, especially at the centre, it decreases sideways the captured area and it is mostly small. The sizes of images are small. The centre of the photograph is known as the *principal point*.

Oblique aerial photograph

Oblique aerial photographs are camera pictures taken at an angle less than 90°. They are taken by a flying object which has its axis directed between the vertical axis and horizontal plane. Oblique aerial photographs can also be divided into *low oblique aerial photographs* which do not show the horizon and *high oblique aerial photograph* which show the horizon (Figure 4.12).

Figure 4.12 *(a) Low oblique aerial photograph*

Figure 4.12 *(b) High oblique aerial photograph*

Oblique aerial photographs give a wide panoramic view of a large area. They provide supplementary information to ground low oblique and ground horizontal photographs. They also cover a large area than ground photographs. Moreover, they give a clear picture of the relief of a given landscape. In addition, the scale of the photograph is medium and less uniform compared to vertical scale.

Based on the extent of area, high oblique aerial photographs extract more information than ground photographs. High oblique aerial photographs are used to supply instant data of such moving objects as vehicles, ship, train and landslide. They can clearly show the layout of different infrastructure like railways, roads and houses making them suitable for land use planning. Oblique aerial photographs have been very useful in wild animal census, locating archaeological sites, strategic military and civilian surveillance and map making.

Photographic scale

The scale of a vertical aerial photograph is a function of the camera's focal length (f) and the altitude or height from which the exposure is made or of the aircraft. The scale of a vertical aerial photograph is given by:

$$S = \frac{f}{H}$$

Where:

f = Camera' focal length

H = Flying height of the aircraft above the ground

S = Scale

Vertical aerial photographs present a true record of angles. However, the horizontal distances are subjected to wide variations due to the flying height of the aircraft and the focal length. Flying height of the aircraft is usually taken from the ground surface at a specified elevation above mean sea level. Focal length of aerial camera varies according to specified need and purpose. In Tanzania, the most commonly used focal lengths are the f = 152 mm and 132 mm.

Note: If one knows the focal length used and the altitude of the aircraft above the ground, it is possible to calculate the approximate scale.

However, when the photograph is taken at a known altitude above mean sea level, the following formula is used to compute the scale.

$$S = \frac{f}{H - h}$$

Where;

h = Average elevation of the photographed area.

New line scale average is applicable when the altitude above the mean sea level and mean elevation of the photographed area are known or given.

Example 1

A camera in an aircraft at an altitude of 3 300 m above the ground was used to take a photograph. Determine the focal length of the camera if the scale of the photograph is 1:25 000.

Solution

Formula

$$S = \frac{f}{H}$$

Data given

Height of the plane (H) above the ground = 3300 m

Scale of photo (S) = 1:25 000

f = ?

$$\frac{1}{25\,000} = \frac{f}{33\,000\text{ m}}$$

$$25\,000 \times f = 33\,000\text{ m} \times 1$$

$$25\,000f = 3\,300 \times 1\,000\text{ mm}$$

$$\frac{25\,000f}{25\,000} = \frac{3300\,000\text{ mm}}{25\,000}$$

Therefore, the focal length = 132 mm

Example 2

Calculate the flying height above mean sea level of an aircraft which produced a vertical aerial photograph at the scale of 1:20 000 given area with a mean ground height of 500 m above the mean sea level using a camera with a focal length of 152 mm.

Solution

Given data

h = 500 m

f = 152 mm

S = 1:20 000

H = ?

Note: h and f should be in the same unit.

Since H is usually in the same unit as h, convert f from mm to m as follows:

1 m = 1 000 mm

? = 152 mm

$$= \frac{152\text{ mm} \times 1\text{ m}}{1\,000\text{ mm}} = 0.152\text{ m}$$

Finally, from

$$S = \frac{f}{H - h}$$

$$\frac{1}{20\,000} = \frac{0.152\text{ m}}{H - 500\text{ m}}$$

$$H - 500\ m = 0.152\ m \times 20\ 000$$

$$H - 500\ m = 3\ 040\ m$$

$$H = 3\ 540\ m$$

Example 3

Find the scale of the topographical map when two landmarks shown on the photograph can be located on a 1:20 000 scale of photograph. The measured distance between the landmark is 50 mm on the photograph and 20 mm on the map.

Solution

$$\frac{MD}{MS} = \frac{PD}{PS}$$

$$\frac{MS \times PD}{PD} = \frac{MD \times PS}{PD}$$

$$MS = \frac{MD \times PS}{PD}$$

Where:

PD = Distance between two known points of photograph

MD = Corresponding distance on the map

MS = Map scale

PS = Photograph scale

Data given:

PD = 50 mm

MD = 20 mm

PS = 1: 20 000

MS = ?

$$MS = \frac{MD \times PS}{PD}$$

$$MS = \frac{20}{50} \times \frac{1}{20000}$$

$$MS = \frac{1}{50000}$$

Therefore, the scale of the topographical map is 1:50 000.

Example 4

Calculate the scale of a vertical aerial photograph taken by an aircraft flying at 19 000 ft above mean sea level using a camera with the focal length of 6 inches. The surface has an average elevation of 100 ft.

Solution

$$S = \frac{f}{H - h}$$

Data given:

Focal length (f) = 6 inches

Flying height (H) = 19 000 ft

Height of the surface (h) = 100 ft

Scale of photo (S) = ?

$$S = \frac{6\ \text{inches}}{19\ 000\ \text{ft} - 100\ \text{ft}}$$

$$= \frac{6\ \text{inches}}{18\ 900\ \text{ft}}$$

To change foot to inches

1 ft = 12 inches

18 900 ft = ?

$$= \frac{12\ \text{inches} \times 18\ 900\ \text{ft}}{1\ \text{ft}}$$

$$= 226\ 800\ \text{inches}$$

$$\text{Scale} = \frac{6\ \text{inches}}{226\ 800\ \text{inches}}$$

$$\text{Scale} = \frac{1}{37\ 800}$$

Therefore, the scale of photograph is 1:37 800

Advantages of vertical aerial photographs over maps

Aerial photographs facilitate studies on the previously inaccessible areas and landscapes such as dense tropical forests, desert interiors and swampland. Aerial photographs are significant decision support systems to the world's environment management. They have been providing the world with tools to predict the future conditions of our surroundings and set policies and strategies to countermeasure them.

By their nature, aerial photographs are raw materials for land use planning. They have also been supplying images to be used for planning and mapping. Plans for settlement, infrastructure layout, disaster management and evacuations, and establishment of developmental programs and projects have made an intensive use of aerial photographs.

Aerial photographs also serve as raw materials for other land and hydrographic surveys. They are important sources of information for land surveys carried for multiple purposes. They are baseline data for other activities, projects and programme. Moreover, based on their ability to capture and record terrestrial and aerial moving objects, aerial photographs have become the tracking systems of traffic and theft management in a larger part of the world.

Limitation of vertical aerial photographs

Set-backs associated with their production could be a barrier to the utilization of aerial photographs. Aerial photographs, other than those taken by non-commercial firms, have been costly. Their availability for local land use planning for example, is impaired by their cost of availability or production. Again, hindrances from natural weather phenomenon like heavy rain, clouds, fog and mist during acquisition have decelerated the speed at which supply could match the demand. The technological development in geographical information system (GIS) and the emergence of free online geographic data sources such as google earth, earth explorer and many others further reduces the frequency of production of aerial photographs.

Factors which may affect the quality of photograph

Nature of the camera to be used: Camera focal-lens, film used and filtration capacity are the most important factors. Accordingly, a camera with a large focal-lens, high filtration capacity towards different aspects such as cloudcover, dust and fog may produce sharp and good photographs, contrary to the camera with a small focal-lens.

Knowledge of the photographer: Knowledge, skills and competence of the photographer on using camera and selecting an appropriate camera location determine the quality of the photograph. A well-trained photographer is capable of producing best photographs.

Position of the photographer: When the photographer is near the objects in terms of distance and height, the caption may be good. The angle at which the photograph is taken also determines the quality of the photograph. That is why the ground-level photograph is regarded as the best qualitative photograph.

Nature of the targeted area: Levelled areas influence a good photograph, especially for ground photograph, unlike the slope and mountainous area which may negatively influence the image quality through distortion.

Weather condition: A good photograph should be taken at the clear day, free from clouds, fog and extreme sunlight.

Time at which photograph taken: The best photograph should neither be taken during the night nor sunny noon time.

Photograph and image interpretation

Photograph interpretation is the process of reading, examining and interpreting photographs in order to obtain reliable information about the natural or cultural features presented. It requires skills and knowledge of many professions. For example, it requires knowledge on types of vegetation to help in analysing climate, types of soil which can be used to identify the possible crops that can grow in the area among the others. Also, knowledge regarding drainage can help to analyse types of rocks, while knowledge on crops and their properties is helpful in analysing the type and nature of soils in the photograph.

Therefore, photograph or image interpretation, as used in this section, is an interplay of interpersonal qualities, environmental knowledge and many others variables. On the other hand, characteristics associated with objects on photographs are equally important in photograph interpretation.

For example, using the visible photograph (Figure 4.13), you can identify the type of image and the angle of the sensor's axis, identify activities, soil type and many other variables.

Figure 4.13: *Tea production farm*

The photograph in Figure 4.13 is a representation of one area in Tanzania in which tea is produced. Therefore, analysis of the photograph in this case will be assisted by prior-knowledge of the areas associated with the cultivation of such crop. The type of crop can support to understand the type of soil and climatic conditions provided you already know the characteristics of the crop seen in the photograph. The crop can also help to describe the nature of drainage of the area, and the general view of the photograph can help to tell the type of photograph.

Processes for photograph interpretation

Interpretation of aerial photographs involves several activities classified into three processes: observation, analysis, and judgement. Observation is concerned with finding typical patterns and characteristics portrayed by different features on the photograph using the basic elements of photograph interpretation. Analysis requires a thorough understanding of features or themes found on the photographed area to determine the meaning of different characteristics observed in the photograph. Judgement is the suggestion of possible features or phenomena related to different characteristics observed in a photograph. Judgement requires a thorough and careful observation and analysis based on the interpreter's experience, knowledge, and skills.

Basic elements for vertical aerial photographs

Interpretation of vertical aerial photographs is based on the following elements:

(a) *Tone or colour or shade:* This element considers the darkness and brightness of the objects. Some areas like forest areas, large water bodies including oceans, lakes and/or rivers appear dark in colour because of less reflective capacity. Some features like beaches, sandy deserts, glaciated areas and all weather roads appear bright in colour because of high reflective capacity. Different objects have different colours. Thus, colour is used to distinguish them.

(b) *Shape:* Different features are of a defined geometric outlines. For example, rivers and roads can be easily identified in a curved elongated shape. Pitches or stadiums are in an oval rounded shape; round-about and water tanks can be identified with circular shape.

(c) *Texture:* This refers to the roughness and smoothness of an object. Some features like forest, residential areas and mountainous areas are shown with rough texture while features like water bodies, grassland and snow appear smooth in texture.

(d) *Pattern:* This refers to the arrangement of the objects, where objects can be in a regular or irregular pattern. Normally, urban settlements and planted vegetation appear in regular patterns while natural forest, shanty town, mountainous regions appear in irregular pattern.

(e) *Size:* If the scale of the photograph is known, then objects of known size of features such as football pitches and tennis courts can be quantified.

(f) *Site:* This technique enables a photograph interpreter to identify a feature according to the environment where such features are found. For example, a feature cutting across a river channel can be a bridge, vegetation along the side of the river such as bamboo and in coastal areas can be mangroves.

(g) *Association:* Is the technique of interpreting features from the existing features. For example, building with a chimney indicates a commercial or industrial area. Forest with wild animals such as giraffe and elephants indicates national parks and existence of tourism industry.

(h) *Shadow:* It helps to give an impression of the depth to a vertical aerial photograph. It helps to distinguish objects such as height of trees or buildings by looking at the direction of the shadow, to the position of the sun and shape of the shadow. Shadow can also be used to estimate the time when the object was photographed.

(i) *Background information:* If all attempt to identify objects have failed, the interpreter must then refer to maps and written descriptions of the area.

Exercise 4.2

1. Carefully study the photograph below and answer the questions that follow:

(a) What physical landscapes does the photograph represent?

(b) Describe two environmental problems that may face the area.

(c) Identify the type of photograph giving at least two evidences.

(d) Briefly describe the mode of formation for the observed physical feature on the photograph.

(e) State the main activities in the area.

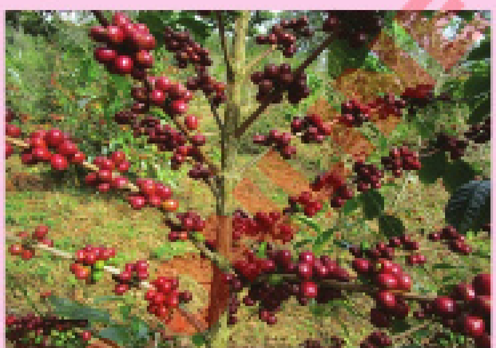
2. What kind of photograph is mostly used in map making and why?

3. Explain the differences between a vertical aerial photograph and a topographical map in relation to the applicability of their end output.

4. Explain aspects to consider before analysing the contents of a ground photograph.

5. Explain the required technical competences in analysing ground photograph.

6. Carefully study the following photograph and answer the questions that follow:



(a) What type of photograph is this ?

(b) With reasons, suggest the type of soil that could favour the growth of such a crop.

(c) What other agricultural crops may be grown in the area where the photograph was taken?

Specific skills for the interpretation of photographs

Apart from the qualities and elements that can help you make a better interpretation of photographs, there are several skills you need to develop for photograph interpretation. The understanding of how you can determine title, estimate time and the season, identify and explain human activities, estimate the size of features, suggest location of the scenery in the place, and estimate direction are pertinently necessary in photo interpretation. These interpretation skills could be achieved in different ways.

Determination of the title can be extracted from photograph information itself. Geographers should be attentive in studying the foreground, middle ground and the background. However, familiarity with the photographed area can give a clue for suggesting the title of the photograph. Similarly, time of the day when the photograph was taken can be estimated. This can easily be detected by using the direction of the shadows of objects. For example, if a photograph was taken during or around noon, shadows cast by objects will be short and centred around the object. Shadows are shortest around midday and they are longest early in the morning or late in the afternoon. The time would be morning if the shadows are in the left hand side of the object. If the shadow is on the right hand side of the object, the photograph should have been taken in the evening.

Consistently, it is also possible to determine the hemisphere in which the photograph was taken or the direction in which the camera faced. Beyond the tropics, the sun never gets overhead, but the shadows behave similar to those in the tropics; that is, they are the shortest at midday and point pole wards. Bright clear skies with dry vegetation could indicate a dry period or season. On the other hand, luxuriant vegetation, young crops in the field, flowering plants, and clouds in the sky could indicate a rainy period or season. Winter could be indicated by the presence of snow on the ground.

The type of clothing worn by the people can also indicate the temperature at the time when the photograph was taken. Also, the activities shown on the photograph can help to determine the time of the year when the photograph was taken. Activities taking place in the photograph can also enable us judge the time when the photograph was taken. For example, cotton is always harvested during noon hours; tea harvest suggests morning time since the leaves have to be taken to the factory in the evening.

Estimating sizes of features on a photograph may be difficult because unlike in maps where the scale is constant throughout the map, in photograph, there is scale distortion such that images become progressively smaller from the camera towards the middle ground and background. The sizes of objects can also be approximated from the size of the familiar object. For example, a coin or a pen may be placed against the rock or any other feature. The size of the coin or pen can then be used to determine the size of the rock or any other object. Heights of trees and houses could be estimated using familiar objects in the photograph such as cars or persons. However, comparison should only be done for features or objects which are on the same level and at the same distance from the camera and not otherwise. For example, a person in the foreground will appear bigger than an elephant in the background.

Weather does not appear directly on photographs. Information has to be gathered from the photograph, both on physical features and human activities. Conclusions can be made by judging from this information. The nature of the sky by the time the photograph was taken can tell the weather conditions of that time. Presence or absence of clouds, the type of clothes worn by the people in the photograph can also indicate the weather condition experienced at the time the photograph was taken.

Interpretation of climate

The types of houses and style of buildings are indicators of the climatic conditions of an area. For example a short house with mud roofs in rural areas in Tanzania indicates semi-arid conditions. The type of crops grown in the field and the type of animals kept can also help to determine the climatic condition of the area. For example, the presence of sugarcane plantations would mean the area is generally warm, while the presence of tea and coffee plantation indicates cool climate. Tea and coffee also indicate presence of high rainfall (reliable and abundant) which is evenly distributed throughout the year. Sisal is a drought resistant crop; thus, it indicates low rainfall in the area.

The natural vegetation present on the photograph can also help to determine the climatic condition within the area. For example, dense forests with tall trees suggest that the area receives heavy and reliable rainfall. Conversely, bushes and grass land indicate dominance of low and unreliable rainfall. Table 4.3 summarises the interpretation of climatic conditions from photographs.

Table 4.3: *Interpretation of climatic type from the photograph*

Object and its characteristics		Type of climate or season
(i)	Cloud covering the sky, green vegetation and grasses	Wet season
(ii)	Plants without leaves (shaded) and dry grasses	Dry season
Nature of crops		
(iii)	Sugarcane, cotton, sisal, cloves, maize, wheat, ground nuts, cashew nuts, and maize. Mostly experience high temperature and moderate rainfall	Tropical climate
(iv)	Coffee, tea, rubber, cocoa and palm oil. Survive in area with reliable rainfall	Equatorial climate or Tropical highland, Montane climate
(v)	Millet, sorghum, and cassava. Thrive or survive mostly in low rainfall and high temperature region	Semi-arid region
Vegetation cover		
(vi)	Dense forest with tall trees	In consideration of other factors, this indicates equatorial climate or mountainous climate. Survive better in areas with heavy rainfall
(vii)	Scattered trees with tall grasses, baobab and swamps. These mostly thrive in areas with moderate rainfall and temperature.	In consideration of other factors, this indicates tropical climate.
(viii)	Thicket, scrubs, grasses, thorn trees, cactus and scrubs thrive or survive mostly in areas with low rainfall and high temperature.	In consideration of other factors, it indicates semi-arid climate or tropical climate.
Kinds of animals		
(ix)	Goat and sheep mostly found in dry conditions.	Semi -arid region

(x)	Giraffe, elephants, lions, and antelopes survive in scattered trees and long grasses.	Tropical climate
(xi)	Monkeys, gorilla, chimpanzee, leopard mostly found in tall trees and forest.	Equatorial climate
Water body		
(xii)	Large inland water body such as a lake, river or dam.	Equatorial climate
(xiii)	Water holes, wells, streams indicate an average amount of temperature and rainfall.	Tropical climate/semi arid
(xiv)	Oasis	Semi-arid and arid climate

Interpretation of human activities

There are several human activities that can be identified or need to be identified on a photograph. These include farming, transport, fishing, forestry and communication.

1. Agriculture or farming: Agriculture includes crop cultivation and livestock keeping.

   Subsistence crop farming: is characterised by several features such as permanent and temporary houses, the land being segmented into small portions and fields separated by hedges sisal or planted trees. Subsistence farming also uses rudimentary tools such as simple hand hoe and machetes.

   Commercial crop farming: is characterised by the presence of cash crops such as tea, coffee, and sisal. Presence of modern machineries and processing factories are also good evidences. Presence of feeder routes within the farm and facilities of collecting produced goods can also help to determine the type of farming. A large farm size is more characterised by presence of large plantations.

   Plantation farming is evidenced by a single crop covering extensive stretches of land. Examples of crops in this regard are sugarcane, tea, sisal and wheat. Storage facilities near the farm also are good evidences. Many labourers in the fields, for example picking tea or coffee and nucleated settlements meant for workers within the farm can tell a lot about plantation farming.

   Livestock farming: this may be grouped into traditional, ranching and dairying. Traditional livestock keeping is characterized by cattle grazing in natural grassland, especially in semi-arid areas. Also, traditional livestock keepers keep large herds of traditional breeds of cattle, sheep and goats, for example, Zebu cattle.

   Ranching can be evidenced by the presence of a large field divided into paddocks, a presence of cow sheds near the farm houses. Presence of windmills and water supplies, for example, water tanks, ponds, water holes, or reservoirs accompanied with cattle dips on the farm may also indicate ranching. Dairying is evidenced by high-grade cows with big udders, milk processing plants and zero grazing units.

There are two aspects to consider on describing the scale of production, these are:

Small scale production: it is suggested by the presence of food crops cultivation, use of local tools such as hand hoe, axes and machete (panga), uses of family labour force and a small farm size.

Large scale production: it is suggested by cash crop production, use of modern tools such as harvesters and a large farm with modern machinery.

2. **Tourism:** is indicated when the photograph shows large water bodies, forest wild animals, hills, coast, caves, historical sites or mountains.
3. Trade: this may be evidenced by the presence of towns and shop malls.
4. Fishing: is indicated by the presence of boats, large water bodies such as oceans, rivers, lakes, dams and net drying yard.
5. Lumbering: is evidenced by the presence of forests, saw mills, chain saws and timber or logs.
6. Industrial manufacturing: is indicated when the photograph shows an industry, a ginnery or a large plantation of sisal, tea or coffee. These crops require processing industry within the farm.
7. Mining: is indicated by the presence of quarry or quarries.

Interpretation of physical features

The landscape is formed by several features. The common features we expect to find on photographs include relief, settlements and drainage.

Relief

Relief features are many and varied in nature they include the following:

Flat landscape

These can be found in both lowlands and uplands. In the lowlands, flat landscape is called a plain. Flat landscapes are normally less than 500 m above the mean sea level and are associated with meandering rivers. Flat areas in uplands (above 500 m above mean sea level) are called plateaus. Plateaus always have steep sloping edges.

Sometimes, flat lands can be identified by the type of crops grown in the area. For example, sugarcane and rice growing is practised on flat lands. Activities such as irrigation also indicate that the area is relatively flat.

Mountainous landscape

A landscape with an elevated landform of more than 2000 m above mean sea level is referred to as mountainous landscape. It is characterised by steep slopes on an individual block of land or an extended mountainous range.

Crops grown in an area can also be used to deduce the altitude of an area. Crops such as pyrethrum, tea, wheat and coffee are highland crops. For example, tea is grown in the Southern highlands in places such as Mufindi (Iringa) and Rungwe (Mbeya) in Tanzania.

Settlements

Settlements can be divided into two major types: rural and urban. Rural settlements can be evidenced by simple architectural designs of semi-permanent houses. The dwellings are also not planned and unevenly distributed. There can also be evidence of farming or fishing activities. Conversely, urban settlements can be indicated by permanent buildings, regular street patterns, buildings with several stores, industrial areas and warehouses, high population density, port facilities such as docks, cranes, containers, and a well-developed communication network (Figures 4.16a).

Activity 4.4

Read materials from various sources, then describe the criteria for categorising settlement patterns of an area. Give reasons for each.

Figure 4.16: *(a) Urban settlements*

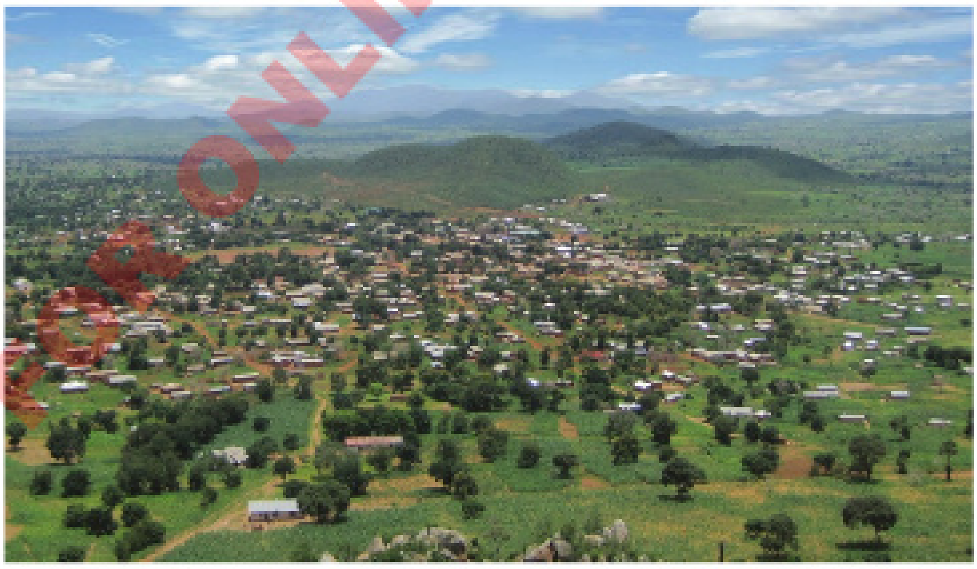


Figure 4.16: *(b) Rural settlements*

Drainage

Drainage is the natural or artificial flow of water from an area by streams to the rivers and draining water from the land to the lakes or oceans. However, drainage may include features such as swamps, water holes, ponds and reservoirs. Water features are easily recognisable in all types of photographs. Deep waters in lakes and oceans appear darker while shallow water in rivers and continental shelves appear brighter. Presence of waterfalls and rapids indicates that the river is flowing along a steep region or landscape. River meanders show that the river is in the middle or old stages. A river delta can be identified by the presence of many channels or dis-tributaries before the river enters the lake or ocean. In aerial photographs, river patterns, for example dendritic, trellis and radial can easily be recognised.

Limitations to quality photograph interpretation

Efficiency and the accuracy of photo interpretation is subject to some barriers developed from the photographing and imaging sensors. The resolution level of the image, the quality and clarity of the photograph may affect interpretation. Photograph interpretation is affected by weather condition at the time when the photograph was taken. For example, cloud cover and fog may affect the quality of the photograph. Also, the angle of the sun when the photograph was taken may determine the darkness or brightness of the photographs. Moreover, quality of the camera lens (size) may determine the quality of the photograph, so can the type of the paper as well as the method used to print the image.

Other additional factors include season of the year whereby during rainy season when vegetation is green, the photograph will appear darker, while it would appear brighter during the dry season when vegetation is less green. The position of the camera towards the object is also important. When photo is taken with a camera near the objects, it will appear clearer than when the camera, is a bit far. The colour of the object also affects interpretation. For instances, objects with black colour may not be clear due to their dark tones while bright coloured objects will be clear.

Activity 4.5

Study the following photograph then answer the questions that follow:

(a) With reasons, name the type of photograph.
(b) Describe the given photograph according to its divisions.
(c) With evidence, identify the time when the photograph was taken.

Exercise 4.3

1. How can you link the various existing types of photographs with the fields such as journalism, agriculture, transport and planning?
2. Suppose you have been given several photographs for analysis. Explain how you would recommend for the quality photographs.
3. Refer to the photograph in Activity 4.2 and answer the following questions:
   (a) With reference to the photograph in Activity 4.2, how does the type of photograph shown differ from a satellite image?
   (b) With evidence(s) from the photograph in Activity 4.2, comment on the following:
      (i) Relief and drainage.
      (ii) The time when the photograph was taken.
      (iii) Economic activities carried out in the area.
      (iv) Giving reasons, identify environmental problems which are likely to face the area.
      (v) Explain ways to overcome those problems.
      (vi) With evidences from the photograph, describe the sections of the photography.
4. Ajmal is a new Geography student at Chimbe Secondary School. He wanted to interpret a ground photograph, but he did not know how to begin. Give him hints on how to interpret his photograph.

Revision exercise 4

1. If distance between village A and B is 12 cm on a photograph, find the scale of the photograph when the corresponding map distance is 24 cm and the map scale is 1: 200 000.
2. An aircraft flying at the height of 5000 m above mean sea level took a photograph of the land at 1200 m using a camera with 152 mm focal length. Calculate the scale of the photograph.
3. Describe the desirable competences for a person intending to interpret the vertical aerial photographs.
4. Assuming the scale is 1:25 000, calculate the height of an area shot by a camera whose focal length is 152 mm, mounted on aircraft flying at 10500 m above the sea level.
5. Briefly explain the way satellite images and extraterrestrial photogram can be used in development planning and management.
6. Illustrate the strength of photographs over maps in obtaining field information.
7. Carefully study the photograph provided and answer the questions that follow.

(a) Name the type of photograph.

(b) Explain the main physical features found in the area.

(c) State the main activity of the area.

(d) Name the scale of activity stated in 8(c) and support your answer by providing three reasons.

(e) At what time was the photograph taken?

8. (a) Why do we need to determine the scale of vertical photograph?

   (b) Describe factors that are likely to affect the scale of photograph.

9. How do different characteristics of aerial photograph diversify the usage of photographs?

10. How would you use different elements for vertical aerial photographs to distinguish the given feature types, grasslands, natural forests, shrubs, forest plantations, orchard trees and lakes?

11. Give a critical classification of aerial photograph.

12. Examine eight factors affecting the quality of aerial photographs.

13. The side of the building measures 20 cm on the photograph taken by a 160 mm focal length camera. If the same side measures 4.25 cm on the 1: 50 000 map, calculate the flying height of the aircraft above the ground.

14. The garden measures 24.4 cm and 34.5cm on a 1: 25 000 map. Determine the measurement of the garden in the photograph if the photo scale is 1: 20 000.

15. Bishara and Grace are best Geography students. Bishara is taking a vertical aerial photograph while Grace is drawing the map of the same area.

   (a) What hints should Bishara use in making the interpretation of such phenomena? Provide six points.

   (b) Describe the main characteristics of the phenomenon taken by Bishara.

Chapter Five

Maps and map interpretation

Introduction

In developing map reading and interpretation capabilities and skills, basic principles must be applied. Map symbols and signs are important tools in map reading and interpretation. The symbols and sign introduced to the map reader should be those which refer to landscape features shown on the map. In this chapter, you will learn about the definition, characteristics, types and map scale. You will also learn measurements on topographical map and the use of principles of map interpretation. The competences developed will enable you to do some daily activities such as distance measurements, area calculation and decision making on socio-economic activities of an area with reference to the skills obtained from map and maps interpretation.

Think about

Knowledge of maps in the manipulation of the earth's spatial relationships

Activity 5.1

1. Suppose you want to show development of physical infrastructures, agricultural projects, settlements, relief and natural vegetation, which type of a map will you use and why?
2. Collect sample(s) of topographical maps from your school library, study them carefully and then answer the following questions:
   (a) Describe the basic principles you have used in reading and interpreting maps.
   (b) Explain the significance of studying topographical maps in your school.
   (c) Name the factors that affect contents of your map.

Maps

The basic principles of map reading are essential for effectively interpreting and using maps. The primary principles include concept before compilation, which emphasizes understanding the map's definition, characteristics, types and nature of the content before creation. The principle of hierarchy with harmony dictates that important features such as vegetation, relief, drainage, settlements and important buildings should stand out while less significant details should not overwhelm the map interpretation, ensuring clarity and focus. The principle of simplicity from sacrifice suggests that a map should convey only necessary information, avoiding confusion and enhancing interpretability. Additionally, cartographic design involves thoughtful use of colors, symbols, typography, and labels tailored to the map's purpose, scale, and audience.

Understanding how to interpret a topographic map allows one to identify geographical features and potential hazards like landslides such as the one occurred in Hanang-Manyara in 2003, and floods, often occurring in Morogoro, and planning, designing and construction of different engineering structures. A well-designed map with these basic components, guided by cartographic principles, will minimize confusion and maximize the effectiveness of the spatial information presented. Henceforward, understanding the basic principles of map reading is essential for effectively interpreting and using maps.

Maps are scaled representation of all or part of the Earth on a flat surface such as sheet of paper or wood. It is a graphical representation of places by using points, lines, symbols and colours to show how selected cultural and natural features are located, arranged and related to one another. Maps can represent distributions and patterns of settlements, streets, transport routes, climate and location of human activities. A person who makes maps is called a *cartographer*.

Main characteristics of a map

Maps of whatever kinds have more or less common defining identities, acting as the characterising features. A typical map is represented to scale since the area on which it is drawn is much smaller compared to the reality on the earth's surface, which is much larger with a lot of features. That is why every map is drawn to a certain scale, the size of which depends on the coverage intended by the cartographer. Therefore, the amount of reduction by which the ground reality is reduced varies from one map to another, due to the use of different types of scales. Usually, the amount of reduction increases with an increase in the ground surface coverage intended to be mapped. Therefore, a map comprises a scale to show the extent or degree by which the ground reality has been reduced to suit the desired area of the material on which the map has been drawn.

The map uses signs and symbols. The surface of the Earth, that a map represents, is of a wide coverage and consists of different features such as vegetation, water bodies, relief, and settlement patterns, among others. Normally, symbolic representation of these features is conventionally agreed. Different symbols are used depending on the nature of the features to be represented. Common symbols used include *point symbols*, which stand for features that appear in point form such as houses, *line symbols* representing features which appear in the form of lines such as roads and *area symbols* that stand for features of wide coverage such as swamps. All these symbols are defined in a key which guides meaningful map interpretation, since each symbol is purposely selected to stand for a particular real object or fact in the real ground surface.

Map is a projection. Maps are drawn from the mathematically transformed curved earth so as to present them on a flat surface. Therefore, maps are representation of the three-dimensional earth into the two dimensional flat surface. A map is a two-dimensional model of reality. It is a representation of certain geographical features that exist in real life.

A map is a generalisation of information and is selective. Since it cannot include everything found in the area, some information is generalised. The extent of generalisation depends on a number of factors including the scale, the purpose of the map and the interest of the cartographer. Generalisation normally increases with the coverage which is determined by the size of the scale. Symbols which stand for the real objects on the earth's surface are generally selected. For instance, a dot may be used to represent houses which are not in the same size and quality.

In addition, a map is communicative as it conveys meaning of different kinds, depending on the nature of the area it represents and the purpose of its production. With important map interpretation skills, even a person who is not familiar with the place on the map can extract or interpret the map and get the meaning represented by the map.

A map is a source of geographical data. It is difficult for human beings to store in mind different trends of events on the earth's surface such as land cover and general spatial distribution of cultural and natural features. Therefore, a map is the best medium in which information is stored. Data from a map can be used in different fields such as pedology, engineering, demography, geology, hydrology and policy formulation for sustainable development. A map shows only a static situation. For example, the map of Babati produced 30 years ago would not show the current situation in the area, but that of 30 years ago. However, due to changes caused by nature and the influence of human activities, geographical areas also change. Due to this, it is important for the user of the map to consider the date of its production to get the most appropriate information.

The value of maps in geography

Maps are widely used in human life, and particularly in Geography as a discipline. Maps act as bases for the description of the area depending on the nature of the fields in which they are applied. Since maps represent the earth's surface, they portray the existing relationship between features such as geomorphology and hydrology.

Maps provide an outstanding base for spatial description of geographical phenomena. The knowledge and skills of map reading and interpretation are keys for understanding the geographical characteristics of the area in terms of relief, climate, drainage system, soil type and their relative significance to human life. The map orients the geography student to the knowledge of geographical skills including cartographical techniques related to map production, and prepares them to become the best cartographers in the future. Maps also enhance critical thinking of the students as they require the integration of knowledge in interpreting and understanding a certain mapped area. For instance, to clearly understand the nature of drainage, one must integrate basic knowledge about geology, pedology and geomorphology.

Maps act as the mirror of past geographical events through which one can see the mapped area today and detect some changes that have occurred overtime. Maps provide much information about the nature and distribution of geographical phenomena such as settlement and settlement patterns. The use of maps enables students to gain insight into the existing relationships between igneous rocks and tectonic activities, relief and drainage, climate and vegetation, and the way these natural relationships influence peoples mode of life, particularly construction and distribution of human settlements. Maps also provide a basis for studying geographical problems such as floods, storms and droughts. Maps provide valuable data for statistical analysis such as population distribution and rainfall patterns. Researchers acquire valuable information for research projects with the help of maps.

Types of maps

Maps are normally of different types. Despite the existing varieties of maps, each of them serves the purpose of its production in the intended area of specialisation. The following are different types of maps and their respective criteria for classification.

(a) Basing on the function and content: maps are classified into topographical and statistical maps.

Topographical maps: are maps designed to represent both cultural and natural features. The word topography is derived from the Greek word 'topos' which means 'place' and 'grahia' which means writing. Topographical maps are drawings of a part of the earth's surface. These maps show location by using compass bearing, grid reference, latitudes, longitudes and names of places. They also show cultural features such as roads, railways, cities, town and dams; landscapes such as mountains, valleys and plateaus; and drainage like rivers, lakes and oceans. Therefore, through interpretation of maps, someone may have a thorough understanding of an existing area even without their physical presence in the area.

Topographical maps are useful for describing features of the earth's surfaces, planning the best uses of land and guiding people to reach their destinations. In general, development of physical infrastructures, agricultural projects and sustainable human settlement depend on the data from topographical maps.

Statistical (distribution) maps: are maps which represent the distribution of geographical phenomena. Geographers are also interested in careful investigation and visualisation of spatial distribution of different geographical events and phenomena, particularly climatic elements like rainfall, temperature, atmospheric pressure, wind speed, sunshine, among others. Moreover, distribution of animals, agricultural activities and movement of goods are among the interests of geographers. Statistical maps are of different types such as dot maps, isoline maps, and choropleth maps among others. Statistical maps are also called quantitative maps as they communicate a message of magnitude. They show variation in value and quantity over a space.

(b) Basing on the degree of accuracy: maps can be classified as surveyed and sketch maps.

Surveyed maps: involve mathematical principles and theories in their production. Since the map represents the earth's surface which is spherical in nature on a flat surface, mathematical principles and theories are applied so as to transform a curved and spherical shape of the Earth to a flat surface. This application gives us topographical maps.

Sketch maps: are types of maps which are roughly drawn with no mathematical basis like scale. They can be drawn even in other subject textbooks such as history to illustrate certain concepts or showing historical sites in a particular country.

(c) Basing on the size of the scale: maps are classified as small scale, medium and large scale maps.

Small scale maps: are drawn by using a small scale to give a large coverage of the earth's surface, even the entire Earth. These maps usually contain large quantity of features and are less detailed, depending on the extent of coverage.

Medium scale maps: are drawn by using a medium scale to provide a medium representation of the earth's surface.

Large-scale *maps:* are drawn to a large scale to cover a small area of the earth's surface, such as school or part of an urban area. These maps contain less quantity of features and are more detailed.

Contents of topographical maps

Topographical maps consist of four major kinds of contents which are *natural contents, cultural contents, contours* and *supportive contents*. Natural contents are all features that are not man-made, they include features such as mountains, valleys, soil types, plateaus, natural vegetation like natural forests, water bodies like rivers, lakes, and oceans. Cultural contents include all man-made features such as roads, railways, buildings, dams, artificial or planted forests and so on. Contours are imaginary lines connecting points of the same elevation to define the configuration of the earth. The supportive contents include information of the map which are provided with the aim of assisting the reader of the map.

Supportive information

Due to the symbolic nature of maps, its correct and meaningful interpretation is impossible without supportive information. Supportive contents of a map are written close but not limited to the margin of the map. They include title, boundary, North direction, scale and key or legend. Others include date of compilation, sheet number, publisher and copyright, grid reference, coordinate system and projection techniques. They are called supportive because they help the map user to interpret the map correctly.

Title

The title, also known as the heading, is an element in a map that describes the theme or subject of a map.

The title sometimes appears as the name of the mapped area or as the combination of the name of the mapped area and the purpose intended to be shown. When it appears just as the name, it is called *general title*, for instance, "Songwe region map". A map with this kind of a title can show a wide range of information. However, when it appears in combination with its purpose, it is called *specific title*. For instance, "Songwe region relief features" will normally intend to show specific information like relief features of Songwe region. The title is normally communicative to some extent as it provides some important clues on the nature of the mapped area in terms of economic activities, drainage, soil quality and climate in particular. The title should always provide an answer to what and where.

Margin

Margin, also known as boundary, is the frame that encloses the map to show the endings and the coverage of the area, often varying in size from one map to another. If the map covers a more extended area, its boundary is likely to be larger, than when it covers a small area. Usually, the map boundary has a uniform space in all sides from the map. But there are maps which show only part of a place within its boundaries. Usually, maps of this type do not have margins or boundaries.

Legend

Legend, also known as a key, is a collection of symbols and signs used in the map and their respective meaning. Though some symbols used in the map are self-explanatory, the key is actually intended to act as the map dictionary, to facilitate the correct and meaningful map interpretation by describing all unknown or unique symbols used on the map. Since map symbols are conventionally agreed, the key helps the map users to translate the map language into ordinary language which can easily be understood. Map language is the system of conventional symbols and signs used to represent features of the mapped area. It also helps the map user to know the relationship between different features on the map. For instance, point (•) symbols that stand for settlements, always appear along the line symbol which stands for roads and rivers.

Map scale

Map scale is the ratio between distance on a map and the actual distance on the ground. Therefore, it allows translation of distance on the map to their equivalent distance on the ground. This simply means that the scale is the determinant factor of each feature that is represented in terms of size. Map scale is important in map making since it commands the coverage and amount of information to be included. It also helps the map users to make the interpretation of the real features they read on the map. The scale also acts as the basis for map classification.

Direction indicator

A direction indicator is an arrow printed on a map to indicate the orientation of the map in reference to cardinals N-S-E-W. The indicator determines the orientation of the map which facilitates interpretation of the map by locating the position of each feature. The direction indicator shows the north direction of the map using North arrows (Figure 5.1) that are used to determine other directions, such as South, West and East. It enables the map user to determine trend and alignment of features on the map, and fix positions of other features by resection and intersection method. Other maps indicate direction by using a *compass rose,* with arrows pointing in all the four cardinal directions.

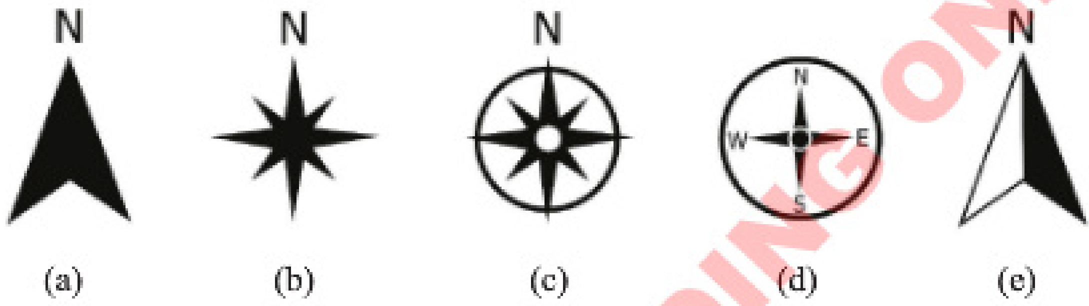


Figure 5.1: *Examples of direction indicators commonly used on topographical maps*

Date of compilation

It indicates the time when the map was published. This guides the readers to select map versions basing on their time barred needs. The date of compilation is very useful in recognising some changes that might have occurred in the area within a given time interval. Normally, land cover such as vegetation, settlement and water sources keep on changing with time. For instance, "Dodoma region map" taken twenty years ago will be quite different from the current map.

Sheet number

Maps sharing the same series are distinguished by the sheet number that shows what geographical area is covered by the map. This means that maps of the same series have different sheet numbers for different areas. Sheet number also shows how many times a given map has been up-dated.

Publisher and copyright owner

Maps indicate the owner of each particular map and the publishing company. The author or publisher of a map is indicated, so as to be familiar with the cartographer to easily get useful clues on information regarding the extent to which the map is biased or reliable. This will be useful in drawing attention on questions such as "Does the map maker or organization have vested interest in how the map is perceived by the map reader?"

Grid references

Grid references refer to the patterns of equally spaced vertical and horizontal lines that are perpendicularly intersecting to each other forming squares. Grid references are based on projected or geographical coordinate system by which different parts and features on the map are located. When based on project coordinate systems, the vertical lines are called eastings as their numbers increase eastwards, while the horizontal ones are called northings as their numbers increase northwards. In reading the grid reference, we start with the eastings and finish with the northings. This is normally determined by the type of projection used in the preparation of a particular map.

Apart from locating the position of different features, the patterns of squares, are used in determining the area of features by grid square method.

Factors that influence the contents of topographical maps

Amount and the nature of the map content are a combined function of a number of factors. Maps are drawn by different cartographers, with different objectives using different scales to represent the earth's surface that differ in terms of nature and amount of the land cover. The following factors determine the content of topographical map.

Scale of the map

The choice of a scale depends on the paper size and extent of the area represented. Under this, the emphasis is put in three cartographic choices of a map scale, namely large, small and medium scale. For example, small scale maps are less detailed. Therefore, maps of the same area produced in the same period of time, by the same cartographer are likely to differ in their content, if their scales are not the same.

Purpose of the map

Any type of a map is made by a cartographer based on a certain aim. In this regard, not all information will be depicted on the maps. The aim of the cartographer is to construct or make a map and determine what need to be shown in a given map. Therefore, the content that appears on the map is determined by desired purpose. If the purpose of the map is to show vegetation distribution, other features like settlements will automatically be excluded on the map.

Date of compilation

The date shows the period of time at which a certain map was produced or published. The information that exists on the earth's surface is not static, it changes over a period of time. Due to this fact, a map shows information which was represented at the time it was produced. Therefore, the maps of the same area drawn at different periods of time possibly differ in terms of contents. For example, the map of Dar es Salaam drawn in 1960's is definitely quite different from the map of Dar es Salaam drawn in 2022.

Nature of the land

Normally, the surface of the Earth that a map represents is not uniformly covered by features. It is covered by features that differ in terms of amount and nature. Some parts of the earth's surface are covered by water bodies like oceans and lakes while others are covered by forests and settlements. Therefore, the map shows what is found in the area including the differences such as physical features found in a given geographical area. It can then be concluded that maps are mirror images of the real surfaces they represent.

Level of technology

The maps drawn by using modern technology like computer, digital camera, and satellite image, contain more features than those produced by hand using data from conventional land surveying like compass and plane table surveying.

Seasons of the year

A map of the same area drawn at different seasons of the year will depict different information. Almost all places do not look the same throughout the four seasons of the year.

Activity 5.2

Prepare a sketch map of your school compound:

(a) State in which category the sketch map falls.

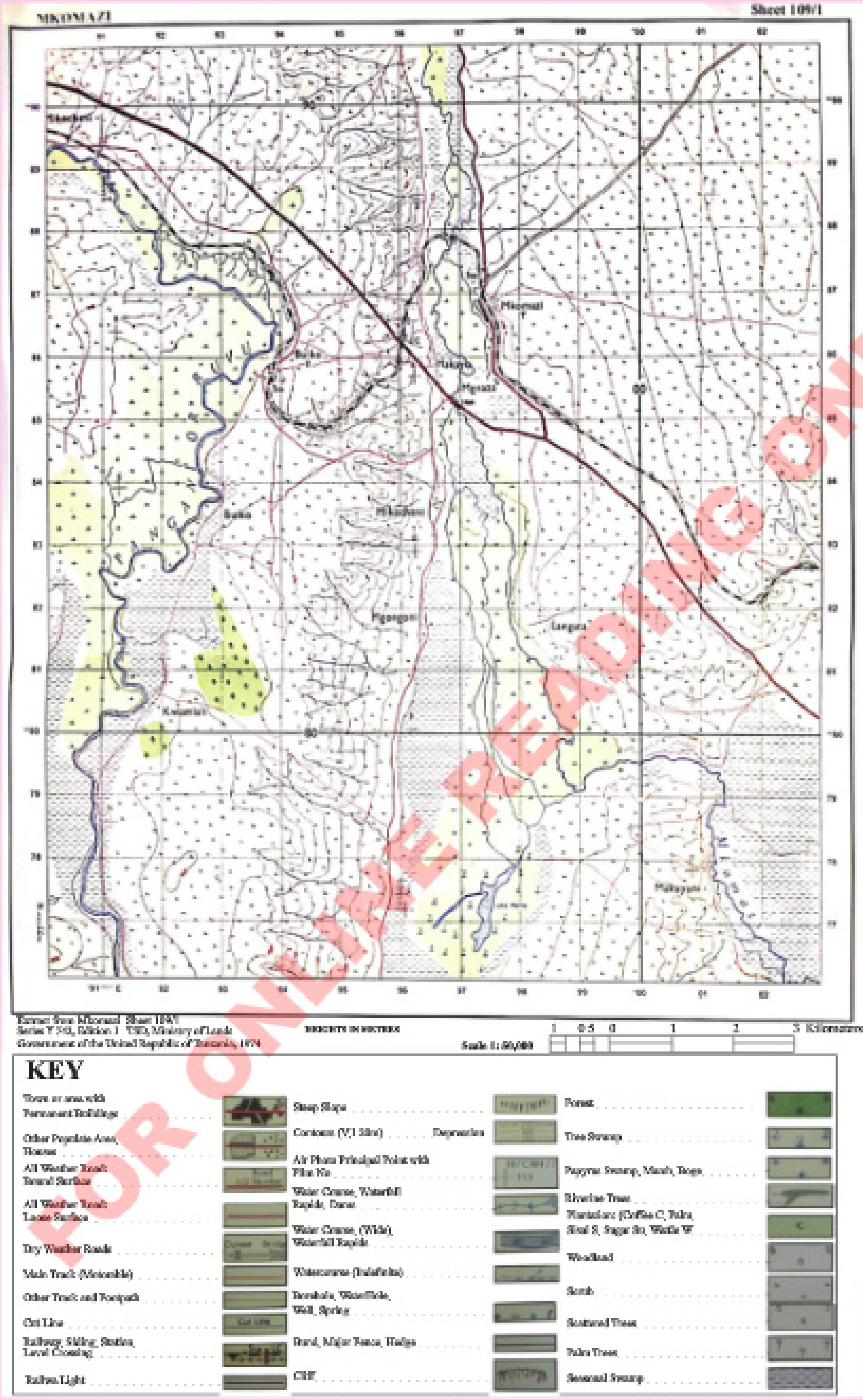
(b) Classify symbols that you have used in the sketch map.

(c) State the title of the sketch map.

(d) Name factors that affect contents of the sketch map.

Exercise 5.1

1. Assume that you have learned the topic on principles of map interpretation and your best friend was absent on the day you learned that topic. Use three (3) points to tell your friend about the basic concept of the topic you have learned.
2. Why do you think maps are important to you?
3. Suppose you want to show the population distribution on a map, which kind of a map will you use and why?
4. Explain the importance of direction indicators to the map maker and map user.
5. Explain factors that influence the content of topographical maps.
6. Classify maps based on the content and degree of accuracy.
7. Study the map extract of Mkomazi sheet 109/1 and answer the questions below:
   (a) Explain six supportive contents of the given map.
   (b) Provide at least four characteristics of the map extract given.
   (c) With examples, classify the content of the given map.
   (d) Highlight five factors that have influenced the content of the given map.
   (e) When was the map printed?
   (f) Who is the owner of the map?


MKOMAZI
Sheet 109/1
Mkomazi
Kakaya
Langata
Extract from Mkomazi Sheet 109/1
Series Y 742, Edition 1 TSD, Ministry of Lands
Government of the United Republic of Tanzania, 1974
HEIGHTS IN METRES
Scale 1: 50,000
1 0.5 0 1 2 3 Kilometres
KEY
Town or area with Permanent Buildings
Other Populate Area, Houses
All Weather Roads Bound Surface
All Weather Roads Loose Surface
Dry Weather Roads
Main Track (Motorable)
Other Track and Footpath
Cut Line
Railway, Siding, Station, Level Crossing
Steep Slope
Contours (V.I 20m) Depression
Air Photo Principal Point with Film No.
Water Course, Waterfall Rapids, Dams
Water Course (Wide), Waterfall Rapids
Watercourse (Indefinite)
Borehole, Waterhole, Well, Spring
Bund, Major Fence, Hedge
Cliff
Forest
Tree Swamp
Papyrus Swamp, Marsh, Bogs
Riverine Trees
Plantation (Coffee C, Palm, Sisal S, Sugar Su, Wattle W
Woodland
Scrub
Scattered Trees
Palm Trees
Seasonal Swamp

Map scale and its importance

Map scale is the relationship or a ratio between the distance measured on the map and its corresponding actual distance on the earth's surface (ground). The earth's surface is much larger than the paper on which a map is drawn. This necessitates reduction of such wide earth's surface, to fit the selected paper size. Therefore, the scale shows the extent to which a given area has been reduced to fit a particular size of the paper. As a reflection of the reduced degree, map scale can be small, large or medium. Map scale is generally very important to the map maker as it determines the content and the coverage of the area being mapped. On the other hand, map scale is important to the map user as it is a tool for interpretation.

In fact, the map scale tells the reader how the map relates to the real world features it represents. To represent the earth's surface on a map requires sufficient adjustment of the scale to cover the desired objective. The extent of reduction is expressed as a ratio or fraction in which the numerator represents the distance on the map while the denominator represents the corresponding ground distance. The larger the denominator, the smaller the scale and the smaller the denominator, the larger the scale. A scale can be expressed as follows:

$$\text{Map scale} = \frac{\text{Map distance}}{\text{Ground distance}}$$

Types of map scale

The map scale is broadly classified into three types, namely; small, medium and large scale as shown in Table 5.1. The selection of the type of map scale is guided by the size of the area to be represented, the size of space to represent and amount of details to be shown on a particular map. If the area to be mapped is large, a small scale is selected, a if the area is small, a large scale is chosen (Table 5.2).

Table 5.1: *Classification of map scales and their units*

S/No.	Type of scale	Scale units in RF	Scale units in statements
1	Small scale map	1:250 000 –1:1 000 000	1 cm to 2.5 km 1cm to 10 km
2	Medium scale map	1:50 000 –1:125 000	1 cm to 0.5 km 1 cm to 1.25 km
3	Large scale map	1:5 000 –1:25 000	1 cm to 0.05 km 1 cm to 0.25 km

Small scale map

Small scales are scales ranging from 1:250 000 to 1:1 000 000 which are used when much detail is not required. The ratio of these scales has the largest denominator indicating a high reduction of their mapped area which is reflected on the size of the resultant maps. A small scale map contains a large quantity of the content of the covered area. The map covers a large area such as a country or a continent or the whole world. Features are greatly reduced and appear very small. In small scale, the content is less detailed.

Medium scale map

Medium scales range from 1:50 000 to 1:125 000 and are used for maps of medium sized areas. They are scales that represent areas which are neither too large nor too small. The maps show moderate contents as the features on the ground are relatively reduced.

Large scale map

Large scales have scales ranging from 1:5 000 to 1:25 000 and are used when we want to represent higher levels of detail. A map drawn using a scale of this type shows detailed information as everything can be seen clearly because of the minimal reduction. This scale however, contains little content due to the small area covered. This scale is used to represent areas like schools or hospital compounds and villages covering small surface areas.

Table 5.2: *Types of scale, surface coverage and details*

Type of scale	Surface area	Detail
Small scale map	Large	Little
Medium scale map	Medium	Moderate
Large scale map	Small	Large

Ways of expressing scales

A scale can be expressed in three different ways, namely; representative fraction, statement, and linear scale.

Representative fraction

Representative fraction (RF) scale is also known as ratio scale. RF is a form of scale which is expressed in ratio and fraction in which the numerator represents the map distance while the denominator represents the ground distance. So, the RF 1:10 000 means 1 unit on the map represents 10 000 units on the ground.

The size of scale in this form can simply be determined by the size of the denominator. The scale indicates how many units on the earth's surface are represented by one unit on the map. It can either be expressed as $\frac{1}{100\,000}$ or 1:100 000. With regard to the given example one centimetre on the map represents 100 000 centimetres (1 kilometre) on the ground. Other common RF scales include 1:63 360 (1 inch to 1 mile) and 1:1 000 000 (1 cm to 10 km). The numerator of a representative fraction is always 1.

Statement scale

It is a written description of a scale, such as 'One centimetre on the map represents one kilometre on the ground' or 'One centimetre to ten kilometres.' Based on these two statements, the first map would show much more detail than the second because one centimetre on the first map covers a much smaller area than the second map. It should be noted that both RF and statement scales are ineffective particularly for a map produced through photocopying and when the size of the map is modified. Under this circumstance there is a possibility of a mismatch of distances in the produced map and the original map. This can however, be addressed using a linear or graphic scale.

Linear scale

Linear scale, also called line scale, bar scale, plain or graphical scale is the way of expressing the scale by the use of a line representing the distance on the ground (Figure 5.2). The linear scale is commonly placed at the bottom of the map. It consists of two main parts, the primary section on the right side with units in kilometres and the secondary section on the left side with units in metres. It helps the map user to determine quickly the ground distance of two points on the map.

However, the scale cannot be directly used to calculate the area, slope, and vertical exaggeration and in redrawing the map. Instead, it demands some skills to prepare it. One of the major advantages of the linear scale is that it is not affected by photocopying.

Figure 5.2: *A simple linear scale*

Also, it is easy to understand. Similarly, it allows direct linear measurement. However, its construction requires time, special skills and experience. Furthermore, the scale can be used by those who are familiar with the units of measurement used in the linear scale.

Scale conversion

Dealing with scale is possible to change one form of scale and express it into another form. For example, changing from representative fraction scale to statement scale, representative fraction scale to linear scale, statement scale to representative fraction scale, statement scale to linear scale, linear scale to representative fraction scale, and from linear scale to statement scale.

Example 1:

Change the statement form of scale to representative fraction scale given that, one centimetre on the map represents half a kilometre on the ground.

Solution

Data given

Statement scale, 1cm = 0.5 km

First, convert ground distance from km to cm. Since 1 km = 100 000 cm, 0.5 km is given as;

$$\frac{0.5\text{ km}\times 100\,000\text{ cm}}{1\text{ km}}$$

$$= 50\,000\text{ cm}$$

Finally, equate map distance in cm to ground distance in cm, and divide both sides by map distance:

$$\frac{1\text{ cm}}{1\text{ cm}} = \frac{50\,000\text{ cm}}{1\text{ cm}}$$

$$1 = 50\,000 = 1{:}50\,000$$

Example 2:

Change the representative fraction scale of 1:50 000 to simple statement scale.

Solution

This means 1 unit to 50 000 units.

If the unit is in centimetres, then

1cm ≈ 50 000 cm

Unit on the ground distances are expressed in kilometres.

$$1\text{ km} = 100\,000\text{ cm}$$

$$? = 50\,000\text{ cm}$$

$$\frac{1\text{ km}\times 50\,000\text{ cm}}{100\,000\text{ cm}}$$

$$= 1\text{ km}\times\frac{5}{10}$$

$$= 0.5\text{ km}$$

Therefore, statement scale is one centimetre on the map represents half a kilometre on the ground.

Exercise 5.2

1. On a map of 1:40 000 scale, the distance measured between town A and town B is 8 cm. What ground distance in kilometres does this represent?
2. What is the R.F scale, if the statement scale is one centimetre on the map represents two kilometres and a half on the ground?
3. Convert the statement scale of one centimetre on the map to one hundred kilometre on the ground into ratio scale.

Construction of linear scale

The construction of a linear scale can be divided into two ways:

(a) Drawing of linear scale

Linear scale can be drawn into forms which are simple or plain or normal scale and as graphic scale.

The procedures of constructing linear scale are basically the same, though graphic scale will involve some more additional steps. The following are the procedures to be considered when constructing a graphic scale:

(i) Determine the scale given such as 1:50 000.

(ii) Convert scale into statement scale. For example, 1:50 000 becomes 1 cm to 0.5 km.

(iii) Use statement scale to find the length of scale or length of baseline (If not guided, choose any reasonable length of baseline or length of scale, for instance 6 km).

(iv) Then, determine the corresponding map distance of the baseline as follows:

$$1\,\text{cm} = 0.5\,\text{km}$$
$$? = 6\,\text{km}$$
$$= \frac{1\,\text{cm} \times 6\,\text{km}}{0.5\,\text{km}}$$
$$= 12\,\text{cm}$$

Thus

6 km = 12 cm

(v) Draw a baseline and divide it into primary and secondary sections.

(vi) Draw perpendicular auxiliary lines at the starting and ending point of the the secondary section, downwards and upwards, respectively from the baseline with ten division.

(vii) Join the points of perpendicular auxiliary lines to divide secondary section into ten equal parts.

(viii) Draw oblique auxiliary lines at both ends of the baseline. These auxiliary lines should be drawn to equal angle between 25° or 30° from the baseline. Auxiliary lines should have a length which can be easily divided to required sections.

(ix) Join the points of auxiliary lines to divide the baseline in equal divisions.

(x) Trace a clear linear scale at the bottom of drawing.

Example

Use 1:50 000 to draw a graphic scale to read 4 km.

Solution

Data given

R.F scale = 1:50 000

Length of the baseline = 4 km

First, convert RF scale to statement scale.

1: 50 000 = 1 cm = 50 000 cm

1km = 100 000 cm

$$? = 50\,000\,\text{cm}$$
$$= \frac{1\,\text{km} \times 50\,000\,\text{cm}}{100\,000\,\text{cm}}$$
$$= 0.5\,\text{km}$$

1cm ≈ 0.5 km

Finally, use the statement scale to determine the corresponding map distance of the baseline.

If 1cm = 0.5 km

? = 4 km

$$= \frac{1\,\text{cm} \times 4\,\text{km}}{0.5\,\text{km}}$$

= 8 cm

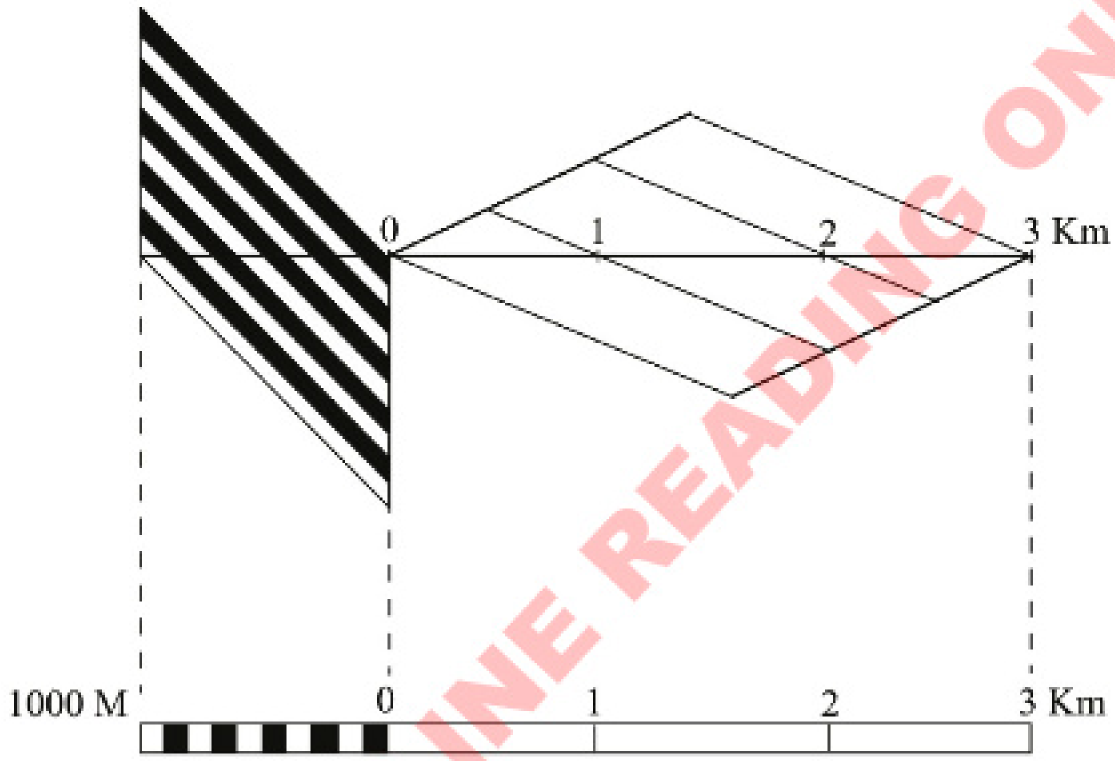


Figure 5.6: *Graphic scale to measure 4 km*

Scale

Primary side 2 cm ≈ 1 km

Secondary side 2 mm ≈ 100 m

Activity 5.3

Draw a linear scale to measure 4.5 km

(b) Linear scale in relation to the speed of a moving object

Graphic scale can also be constructed from the relationship between distance and time that describes a speed (that is, speed is the ratio of distance to time) of a moving body or object such as a motorcycle, train or any other object in motion.

Example

A bus travels at a speed of 180 km/h from Morogoro to Dodoma covering a map distance of 30 cm for 20 minutes.

(a) Calculate ground distance
(b) Determine the statement scale
(c) Draw the graphic scale

Solution

Data given

Speed of the bus = 180 km/h

Map distance = 30 cm

Time taken = 20 minutes

Formula: $\text{Speed} = \frac{\text{Distance}}{\text{Time}}$

$$\text{Distance} = \text{Speed} \times \text{Time}$$

$$= \frac{180 \text{ km}}{\text{h}} \times \frac{20}{60} \text{h}$$

$$= 60 \text{ km}$$

Ground distance = 60 km

Since 30 cm on map is equivalent to 60 km on ground, then:

$30 \text{ cm} = 60 \text{ km}$

$1 \text{ cm} = ?$

$$= \frac{1 \text{ cm} \times 60 \text{ km}}{30 \text{ cm}} = 2 \text{ km}$$

$1 \text{ cm} \approx 60 \text{ km}$

In statement, one centimetre on the map represents two kilometres on the ground.

Determining the baseline length

Since the length of the scale is not provided, we can choose any

So, let it be 22 km

Then,

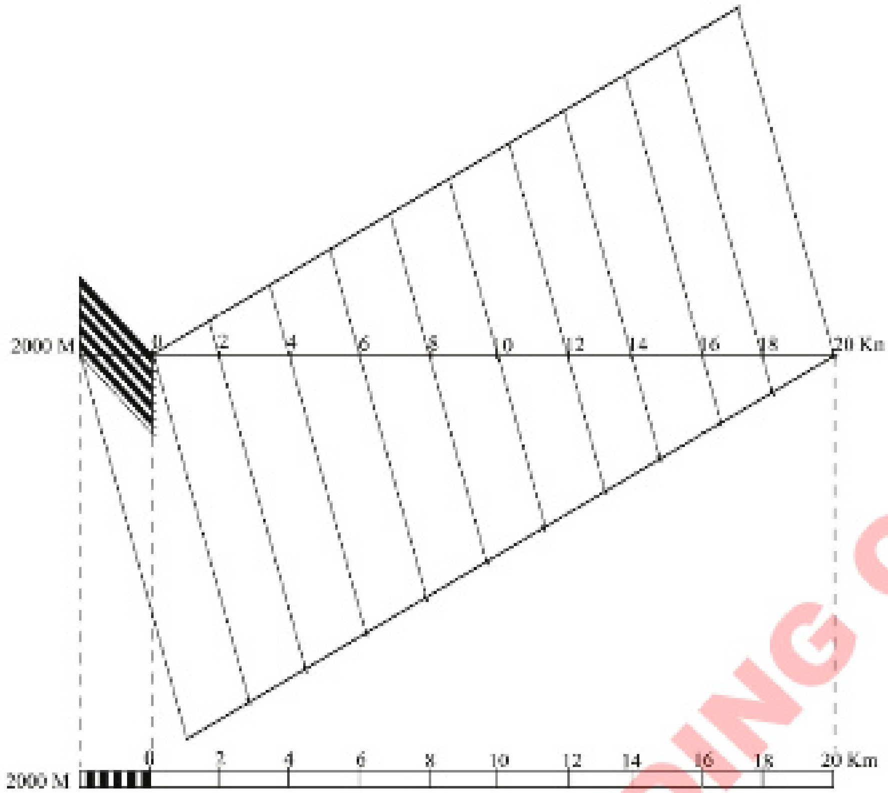
If $1 \text{ cm} = 2 \text{ km}$

$? = 22 \text{ km}$

$$= \frac{1 \text{ cm} \times 22 \text{ km}}{2 \text{ km}}$$

$= 11 \text{ cm}$

The baseline length = 11 cm



Scale

Primary side = 1 cm ≈ 2 km

Secondary side = 1 mm ≈ 200 m

Figure 5.7: *Graphic scale to measure 22 km*

Linear scale based on a given distance can be drawn when RF scale and specific distance on the ground are given. See the example below.

Example

A Bus Rapid Transit (Mwendokasi) in Dar es Salaam, travels at a speed of 70 km/hr, covering the distance of the road between Kivukoni to Mbezi Magufuli bus terminal in 30 min. Assuming the same distance measured on a map is 7 cm, construct a linear scale to read 60 km.

Solution

Data given

Speed of the bus = 70 km/h

Time taken = 30 min

Map distance = 7 cm

Ground Distance = ?

Formula:

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

Distance = Speed × Time

To change minutes into hours

= 70 km/h × 30 min

If 1 h = 60 min

? = 30 min

$$= \frac{1\,h \times 30\,min}{60\,min}$$

= 0.5 h

Distance = Speed × Time

= 70 km/h × 0.5 h

= 35 km

To find the scale of the map (Map scale)

7 cm on map ≈ 35 km on the ground

$$\frac{7\,cm}{7} = \frac{35\,cm}{7}$$

1 cm = 5 km

To find the length of the baseline

If 1cm = 5 km

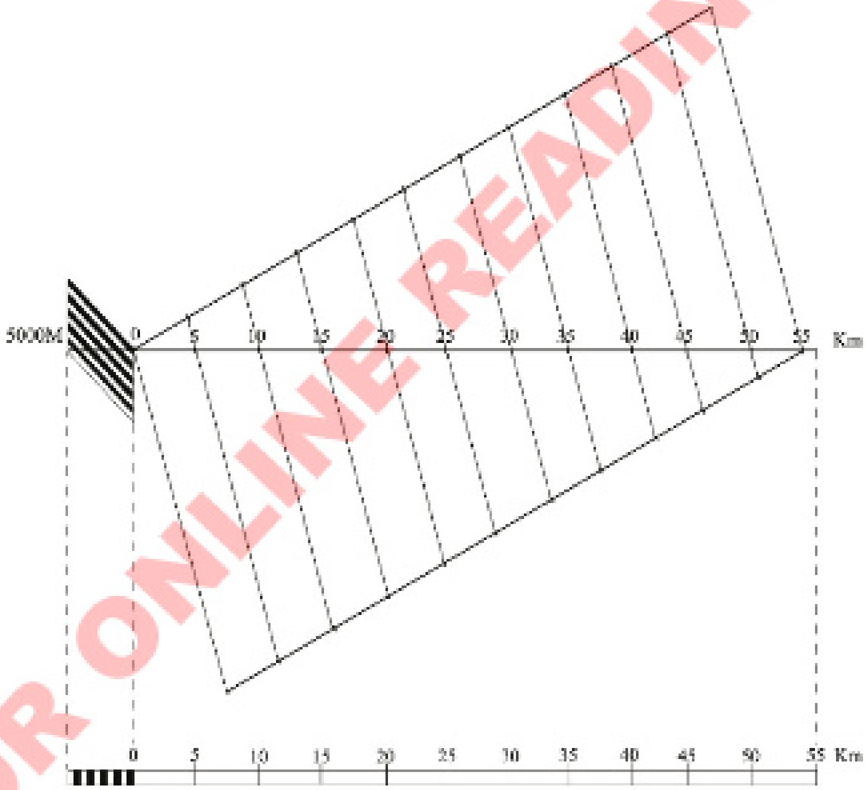
? = 60 km

$$\frac{1cm \times 60\,km}{5\,km}$$

= 12 cm

Base line length = 12 cm (It represents 60 km). In the baseline, every 1cm will represent 5 km.

To construct a linear scale.



Scale

Primary side = 1 cm represents 5 km

Secondary side = 1 mm represents 500 m

Figure 5.8: *Graphic scale to read 60 km*

Exercise 5.3

1. Explain the uses of a map scale to the map maker and map user. Write 3 points for each.
2. Describe basic procedures for the preparation of the graphical scale and state its strength.
3. Explain the differences between primary and secondary sections of a graphical scale.

Activity 5.4

1. Search for a topographical map and prepare a graphical scale of 5 km and show the reading of 4.7 km.
2. Summarise the procedures that were considered to prepare the graphical scale in (1) above.

Map interpretation

Map interpretation refers to the identification of features or phenomena on a map using symbols and signs. It also involves estimating positions, distances, direction and areas of different features describing configuration of terrains.

Measurements on topographical maps

With the map scale, the size and length of both natural and man-made features can accurately be transferred from the map to the actual ground. It is also possible to know the extent of steepness on the real ground surface. The method used in measurement of the length and size, depends on the nature of the feature in terms of shape and straightness. Among the common measurements in topographical maps include distance and area.

Distance measurements

Measurement of distances on maps involves features that occur in linear forms such as roads, coastline, rivers and railway lines. It can also involve two points that are not connected by any elongated feature. Basing on such a concept, distance measured on the map are of two types, namely; straight and curved or winding distances.

Straight distance

To measure the distance of this kind, a line is drawn to connect the identified points, then the distance is directly measured by the ruler and the actual distance is obtained with the aid of the linear scale, or by using the representative fraction scale. This kind of distance is much less common in elongated features.

Winding/curved distances

This is very common in elongated features such as roads, railways and pipelines. The methods for measuring distance of curved features include the following: a pair of dividers, a string and a straight edge of the paper.

A pair of dividers

It is commonly used to measure short straight distances between two points on a map. For distances shorter that the span of the divider, the following procedures are followed:

(i) Identify the starting and the ending points where measurements are to be taken;

(ii) Set the dividers between the two

points;

(iii) Then, move the dividers to the scale bar and read the distance as shown in Figure 5.3.

Map scale 1:100 000

Figure 5.3: *Marking of distance on a linear scale using a pair of dividers*

For distances longer than the span of the pair of dividers, the following procedures are followed:

(i) Identify the starting and the ending points where measurements are to be taken;

(ii) Set the divider to a known distance interval using the scale bar, say a quarter of a kilometre (0.25);

(iii) Then, set the dividers at the starting points along the straight line connecting the ending point.

(iv) Walk the divider along the straight line by rotating it from point to point and count the number of the complete intervals travelled, say 10 for instance.

(v) If the last interval, the eleventh in this case is beyond the ending point, adjust the divider to coincide with the ending point. Move the adjusted divider to scale bar and measure the distance of the last segment.

(vi) Finally, the distance between the two points is given:
Distance = *Number of complete interval* × *Distance Interval* + *Distance of the last segment.*

If distance interval and the distance of the last segment are map distance, the conversion to ground distance is necessary. This conversion is done using statement scale. For example, if the measured map distance between two points is 37 cm and map scale is 1:100 000, the corresponding ground distance is determined through the following procedures:

(i) Convert the representative fractional scale into statement scale;

1:100 000 = 1 cm : 100 000 cm

Since, 1 km = 100 000 cm

? = 100 000 cm

$$= \frac{1\,\text{km} \times 100\,000\,\text{cm}}{100\,000\,\text{cm}}$$

Statement scale is 1 cm : 1 km

(ii) Use statement scale to convert map distance as follows:

Since 1 cm = 1 km

37 cm = ?

$$\frac{1\,\text{km} \times 37\,\text{cm}}{1\,\text{cm}} = 37\,\text{km}$$

Therefore, the equivalent ground distance is 37 km.

String or thread

A piece of a thread can be used to measure curved distances on a map using the following procedures.

Procedures

(i) Identify the two end points you want to take measurements.

(ii) Lay a piece of a string along the points.

(iii) Shift the string onto the linear scale or ruler to read the actual distance (using a linear scale) or map distance (using a ruler).

(iv) If map distance is measured, use statement scale to convert it into ground distance.

Example

Use Figure 5.4 to determine the ground distance of the curved line by using thread method provided that the map scale is 1:25 000.

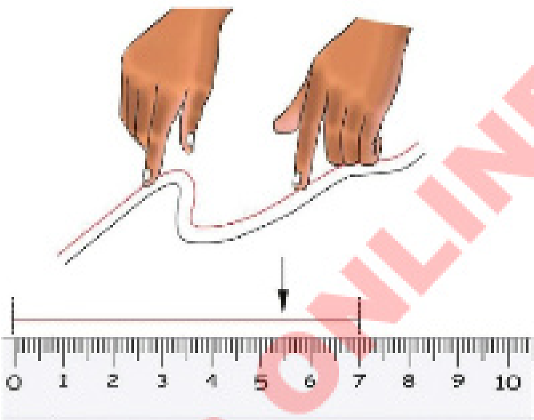


Figure 5.4: *Measuring distance by using a string or thread*

Solution

Data given

Map distance = 7 cm

Map scale = 1:25 000

Constant 1 km = 100 000 cm

From the data given,

1 km = 100 000 cm

?=25 000 cm

$$= \frac{1\text{ km} \times 25\,000\text{ cm}}{100\,000\text{ cm}}$$

= 0.25 km

1 cm = 0.25 km

7 cm = ?

$$= \frac{0.25\text{ cm} \times 1\text{ km}}{1\text{ cm}}$$

= 1.75 km

Therefore, the ground distance of the curved line =1.75 km.

Straight edge of a paper

A piece of paper with a straight edge can be used to measure curved distances (Figure 5.5) using the following procedures.

(i) Identify the two end points of the feature you want to measure.

(ii) Divide the distance into small short straight distances.

(iii) Take a straight edge of paper and lay it on the map and move all points defining the shot straight distances between the two end points.

(iv) Shift the piece of paper onto the linear scale or ruler to get the ground or map distance, respectively.

(v) If map distance is measured using a ruler, use statement scale to convert it into ground distance.

Example

Find the ground distance of the curved feature in Figure 5.5 by using a straight edge of paper method, provided that the map scale is 1:50 000 and the measured map distance is 8.6 cm.

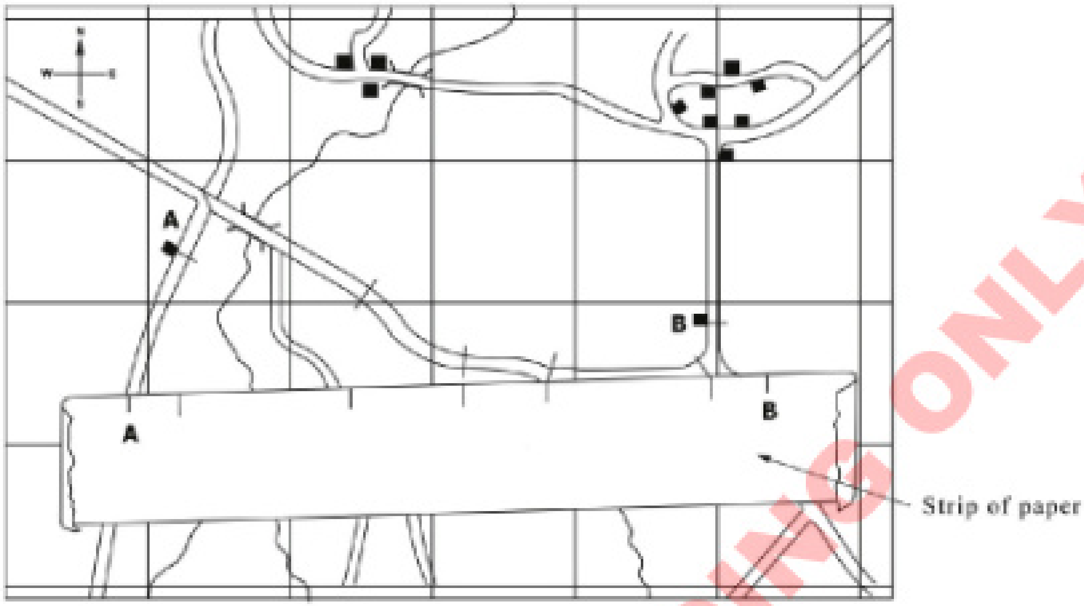


Figure 5.5: *Measuring distance of the curved feature by using a straight edge of a paper*

Solution

Data given

Map distance 8.6 cm

Map scale = 1: 50 000

Ground distance = ?

From the data given,

1 km =100 000 cm

? = 50 000 cm

$$= \frac{1\text{km} \times 50\ 000\text{cm}}{100\ 000\ \text{cm}}$$

$= 0.5$ km

1 cm = 0.5 km

8.6 cm = ?

$$= \frac{8.6\ \text{cm} \times 0.5\ \text{km}}{1\ \text{cm}}$$

$= 4.3$ km

Therefore, the ground distance of the curved feature is 4.3 km.

Area measurements

In topographical maps, areas of natural features such as swamps and cultural features such as race truck can be actually determined on the ground. The method applied in determining the area depends on the shape of the particular feature. Actually, the shape of some features are regular while others are irregular. It is the interest of the map user to determine the area coverage of features for social, economic and cultural purposes.

Regular shaped areas

The area of regular shaped features such as triangles, rectangles, trapezium and circles on the topographical maps can be simply determined by applying mathematical formula depending on the shape of that feature. For instance, to calculate the area of a rectangle, multiply its length by width. Remember, if you want to determine the area in ground measurements, use the map scale to convert length and width from the map into ground distances. The formulas for calculating areas of different shapes are shown in Figure 5.12.

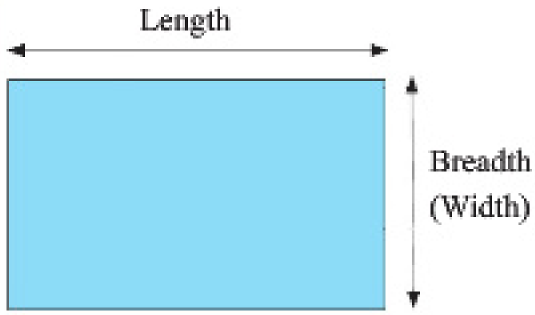
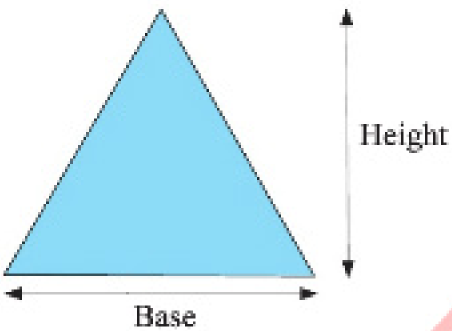
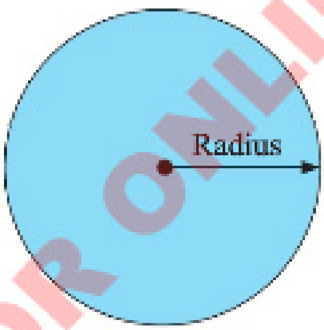
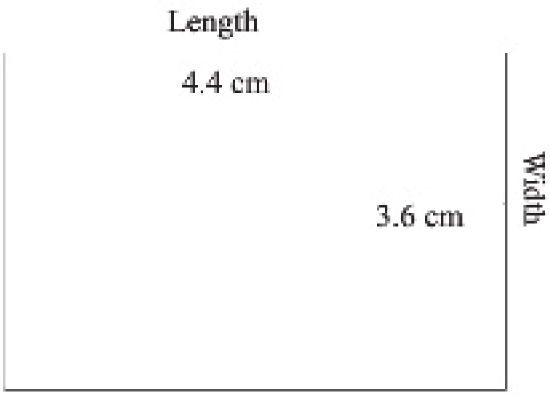
Shape	Formula
 (a) Rectangle	*Area = Length × Broadth/Width*
 (b) Triangle	$Area = \frac{1}{2} \times Base \times Height$
 (c) Circle	$Area = \pi \times radius^2$ or πr^2

Figure 5. 12: *Shapes and formulas for calculating areas*

Example

Find the ground area of the following feature.



Scale 1 : 50 000 cm

Solution

Formula: L (to scale) × W (to scale)

Data given

Map length = 4.4 cm

Map width = 3.6 cm

Map scale = 1:50 000

Ground length = ?

Ground width = ?

From the data given,

1 km = 100 000 cm

? = 50 000 cm

$$= \frac{1\text{ km} \times 50\,000\text{ cm}}{100\,000\text{ cm}}$$

= 0.5 km

1 cm = 0.5 km

Ground length

If 1 cm = 0.5 km

4.4 cm = ?

$$= \frac{4.4\text{ cm} \times 0.5\text{ km}}{1\text{ cm}}$$

= 2.2 km

Ground length = 2.2 km

Ground width

If, 1cm = 0.5 km

3.6 cm = ?

$$= \frac{3.6\text{ cm} \times 0.5\text{ km}}{1\text{ cm}}$$

= 1.8 km

Ground width = 1.8 km

Area = ground length x ground width

= 2.2 km × 1.8 km

= 3.96 km^2

Irregular shaped areas

Irregular shapes on topographic maps include swamps, lakes, forest and the like. The area of such features is obtained by using various methods such as grid method or square method or tracing method, strip method, graph paper method, and geometrical figures method.

Grid method

This is the method which is more accurate for calculating areas of irregular features. In this method, the shape of the land which has to be calculated is covered by complete and incomplete grid (squares). Grid method involves the following procedures.

(i) Count the number of complete grid units (squares) covered in the required area;

(ii) Count the number of incomplete grid units (squares);

(iii) Divide the total number of incomplete squares by 2;

(iv) Add the results in (i) and (iii) to get total number of squares;

Therefore, the total number of squares =

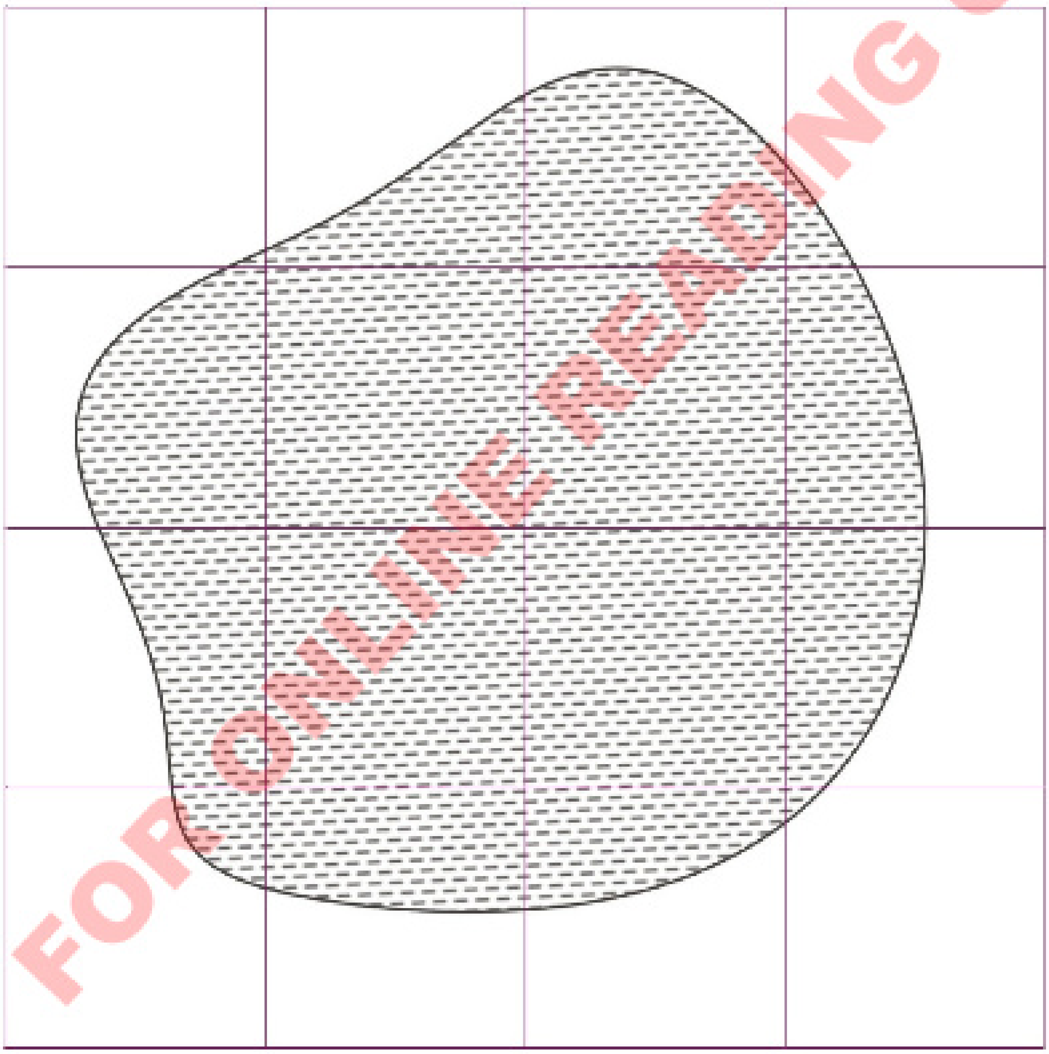
$$\text{Complete squares} + \frac{\text{Incomplete squares}}{2}$$

(v) Change the RF scale into simple statement scale;

(vi) Find the area of one square; and

(vii) Multiply the area of one square by the total number of squares counted.

Example, find the area covered by the pond in Figure 5.6.



Scale 1: 50000

Figure 5.6: *Area covered by the pond*

Solution

Complete squares = 4

Incomplete squares = 12

Map scale = 1:50000

Total number of squares = $\text{Complete squares} + \dfrac{\text{Incomplete squares}}{2}$

$= 4 + \dfrac{12}{2}$

$= 4 + 6$

$= 10$ squares

Map scale = 1:50000

= 1 cm = 0.5 km

Measure the sides of grids using a ruler, say 2 cm and convert them into ground distance using statement scale as indicated below:

1 cm = 0.5 km

2 cm = ?

$= \dfrac{2\text{ cm} \times 0.5\text{ km}}{1\text{ cm}}$

= 1 km

Find the ground area of one grid as:

$1\text{ km} \times 1\text{ km} = 1\text{ km}^2$

Finally, find the total area of the pond as follows:

Area = Total number of grids × area of one grid.

Area = 10 grids × 1 km^2 /grid = 10 km^2

∴ Area of the pond is 10 km^2

The method is useful on a map with grid lines.

The strip method

The strip method is used to find the area of irregular shaped features which involve the division of the feature into strips of equal width. Strip method involves the following procedures:

(i) Divide the required area into strips of equal width;

(ii) Measure the length of each strip using a ruler;

(iii) Convert the map length and width of each strip into ground distance using statement scale;

(iv) Calculate the area of each strip by the formula length x width; and

(v) Sum the areas of individual strips to get the area of the desired figure.

Example

A map shown in Figure 5.7 was drawn to the scale of 1:25000 and divided into 5 strips 1, 2, 3, 4 and 5 of equal width of 1 cm. If the length of strips 1, 2, 3, 4 and 5 were measured as 4 cm, 6 cm, 5 cm, 6 cm and 5cm, respectively, determine the area of the figure.

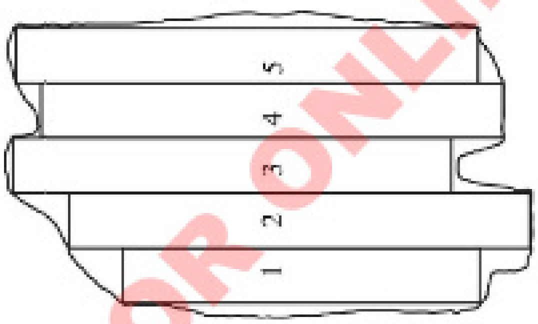


Figure 5.7: *Strip method*

Solution

Data given

Map scale = 1:25000

Strip 1 = 1 cm by 4 cm

Strip 2 =1 cm by 6 cm

Strip 3 =1 cm by 5 cm

Strip 4 = 1 cm by 6 cm

Strip 5 = 1 cm by 5 cm

1 km = 100 000 cm

? = 25 000 cm

$$= \frac{1\text{ km} \times 25\,000\text{ cm}}{100\,000\text{ cm}}$$

$$= 0.25\text{ km}$$

Then, convert the width and map length of strips into ground length(s).

The width of each strip will be obtained as follows:

1 cm = 0.25 km

1cm = ?

Width of strip = 0.25 km

Length of strip 1

1 cm = 0.25 km

4 cm = ?

$$\text{Length} = \frac{4\text{ cm} \times 0.25\text{ km}}{1\text{ cm}} = 1\text{ km}$$

Length of the strips 2 and 4

1 cm = 0.25 km

6 cm = ?

$$\text{Length} = \frac{6\text{ cm} \times 0.25\text{ km}}{1\text{ cm}} = 1.5\text{ km}$$

Length of the strips 3 and 5

1 cm = 0.25 km

5 cm = ?

$$\text{Length} = \frac{5\text{ cm} \times 0.25\text{ km}}{1\text{ cm}}$$

$$= 1.25\text{ km}$$

Then, calculate the area of each strip.

Area of strip 1 = Length of strip 1 × Width of strip 1
1 km × 0.25 km = 0.25 km²

Area of strip 2 = Length of strip 2 × Width of strip 2
1.5 km × 0.25 km = 0.375 km²

Area of strip 3 = Length of strip 3 × Width of strip 3
1.25 km × 0.25 km = 0.3125 km²

Area of strip 4 = Length of strip 4 × Width of strip 4
1.5 km × 0.25 km = 0.3175 km²

Area of strip 5 = Length of strip 5 × Width of strip 5
1.25 km × 0.25 km = 0.3125 km²

Finally, sum the areas of the five strips to get the total area of the figure of interest. In our case, the total area = 0.25 km² + 0.375 km² + 0.3125 km² + 0.3175 km² + 0.3125 km²

Therefore, area = 1.625 km²

The geometrical figures method

This is also called a division method. It involves the division of the feature into several geometrical figures such as triangles, rectangles, and squares depending on the shape of the feature itself. The area of the whole feature is the sum of the areas of all individual geometrical figures. Geometrical figures method involves the following procedures:

(i) Divide the area into convenient geometrical figures such as A, B, C, D and E as shown in Figure 5.8;

(ii) Measure ground or map distance of each side of the geometrical figure using a linear scale or a ruler. If map distances are measured, convert them into ground distance using statement scale;

(iii) By using appropriate formulas, calculate the area of each geometrical figures separately; and

(iv) Sum the areas of individual geometrical figures to get the total area of the entire figure.

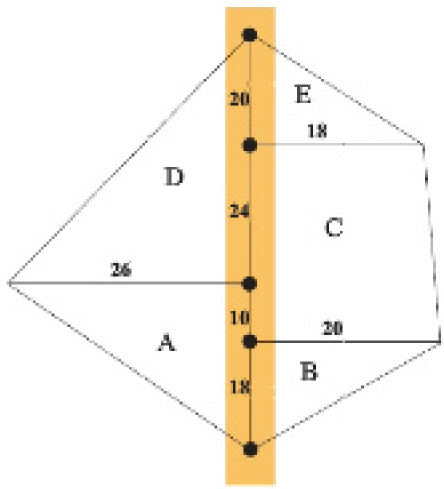


Figure 5.8: *Geometrical figures method*

Activity 5.5

Figure 5.8 in a map drawn to a scale of 1:100 000 was divided into 5 geometrical figures. If the dimensions of the geometrical figures are map distances in centimetres, calculate the ground area of Figure 5.8 by using geometrical figures method.

Map enlargement and reduction

Map enlargement and reduction can be described as a cartographical technique of increasing or decreasing the size of a map in a given area according to scale.

Map reduction and enlargement (re-drawing the map) is governed by two mathematical principles. Firstly, when the small scale map is redrawn by using a large scale, its size becomes large, its content becomes detailed while the covered area is reduced. This process is referred to as map enlargement. Secondly, when the large scale map is redrawn by using a small scale, its size becomes smaller, less detailed covering a large area. This process is referred to as map reduction. Both of them involve the following redrawing procedures:

(i) Study the map or required area of the map to be redrawn.

(ii) Identify the map scale and covert it into statement.

(iii) Determine changing factor/ scale factor

$$\text{Scale factor} = \frac{\text{New scale}}{\text{Old scale}}$$

(iv) Measure the length, width and side of the grid square. But if the distances are given, convert the map distance into ground distance.

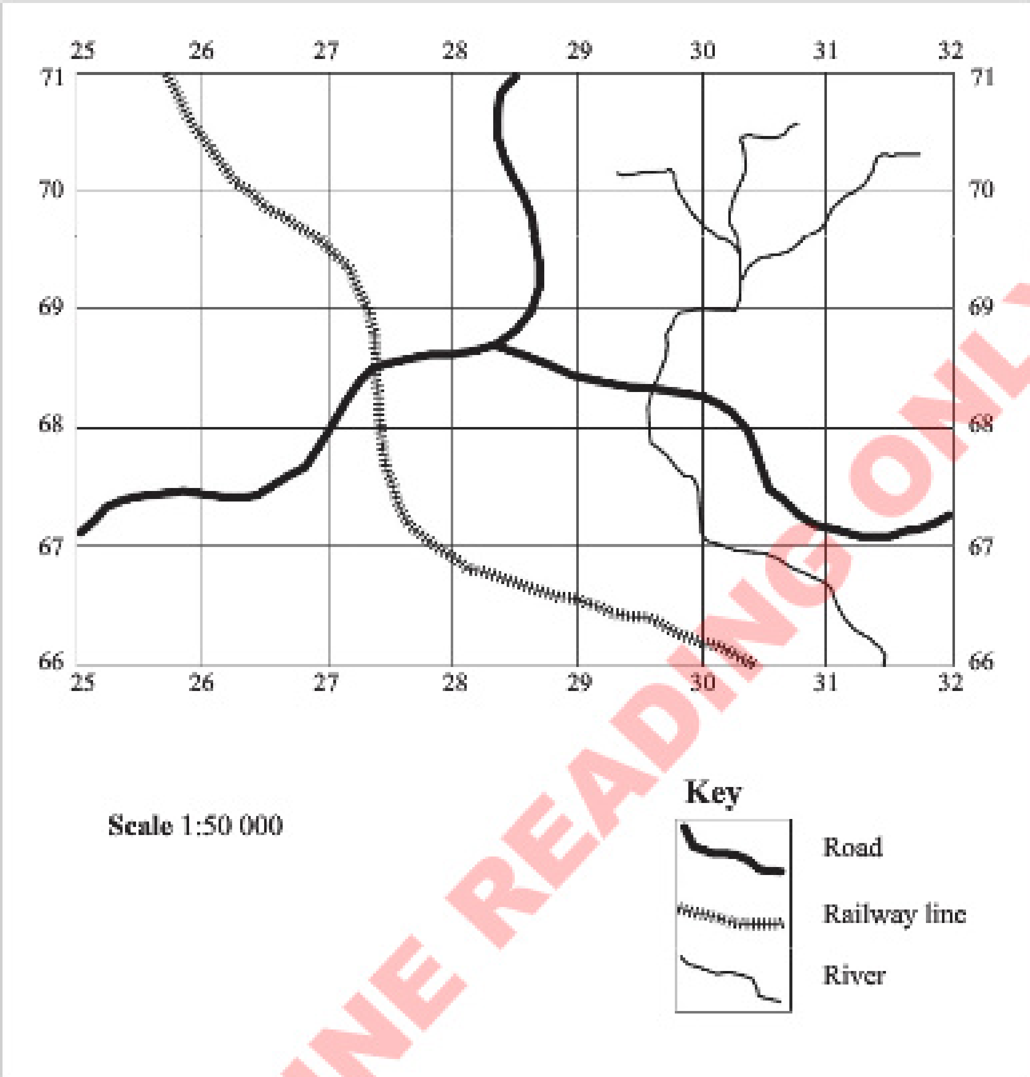
(v) Using the given map scale for re-drawing, convert or change the old map dimensions into new map dimensions, by using the scale factor.

(vi) Redraw the map and if the original map had grid references, then indicate them in the new map.

(vii) Show the main features and remember to show the title, key and the scale.

Example

Re-draw the map provided below by using the scale of 1:100000



Solution

Data given

Old map scale = 1:50000

New map scale =1:100000

Side of each grid square = 2cm

Old width = 10 cm

Old length = 14 cm

New side =?

New width =?

New length =?

Since the new scale is smaller than the old scale, then the resultant map will be small in size (reduction).

Then;

$$\text{Scale factor} = \frac{\text{New scale}}{\text{Old scale}}$$

$$= \frac{1/100\,000}{1/50\,000}$$

$$= \frac{1}{100\,000} \times \frac{50\,000}{1}$$

$$= \frac{50\,000}{100\,000}$$

$$= \frac{1}{2}$$

Finding the new dimensions:

New side of a grid = Old side × Scale factor

$= 2 \text{ cm} \times \frac{1}{2}$

$= 1 \text{ cm}$

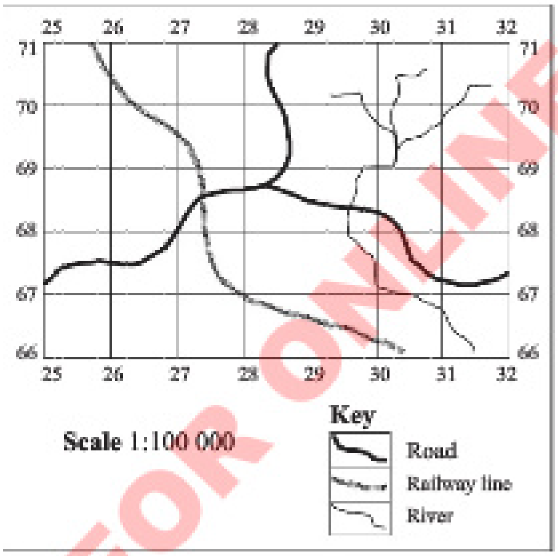
New length = Old length × Scale factor

$= 14 \text{ cm} \times \frac{1}{2} = 7 \text{ cm}$

New width = Old width × Scale factor

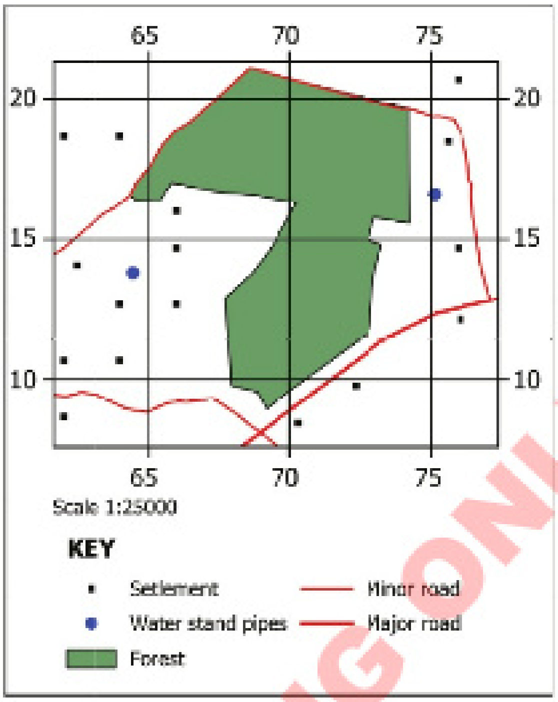
$= 10 \text{ cm} \times \frac{1}{2}$

$= 5 \text{ cm}$



Example 2

Study the hypothetical map provided and redraw it using a scale of 1:12500



Solution

Data given

Old map scale = 1:25000

New map scale =1:12500

Old side of grid square = 2 cm

Old width = 6.3 cm

Old length = 5.5 cm

New side of the grid square =?

New width =?

New length =?

Comparison between the old and the new scale shows that the new scale is larger than the old scale. Therefore, the resultant map will be larger in size than the old map (Enlargement).

$$\text{Scale factor} = \frac{\text{New scale}}{\text{Old scale}}$$

$$= \frac{1/12\,500}{1/25\,000}$$

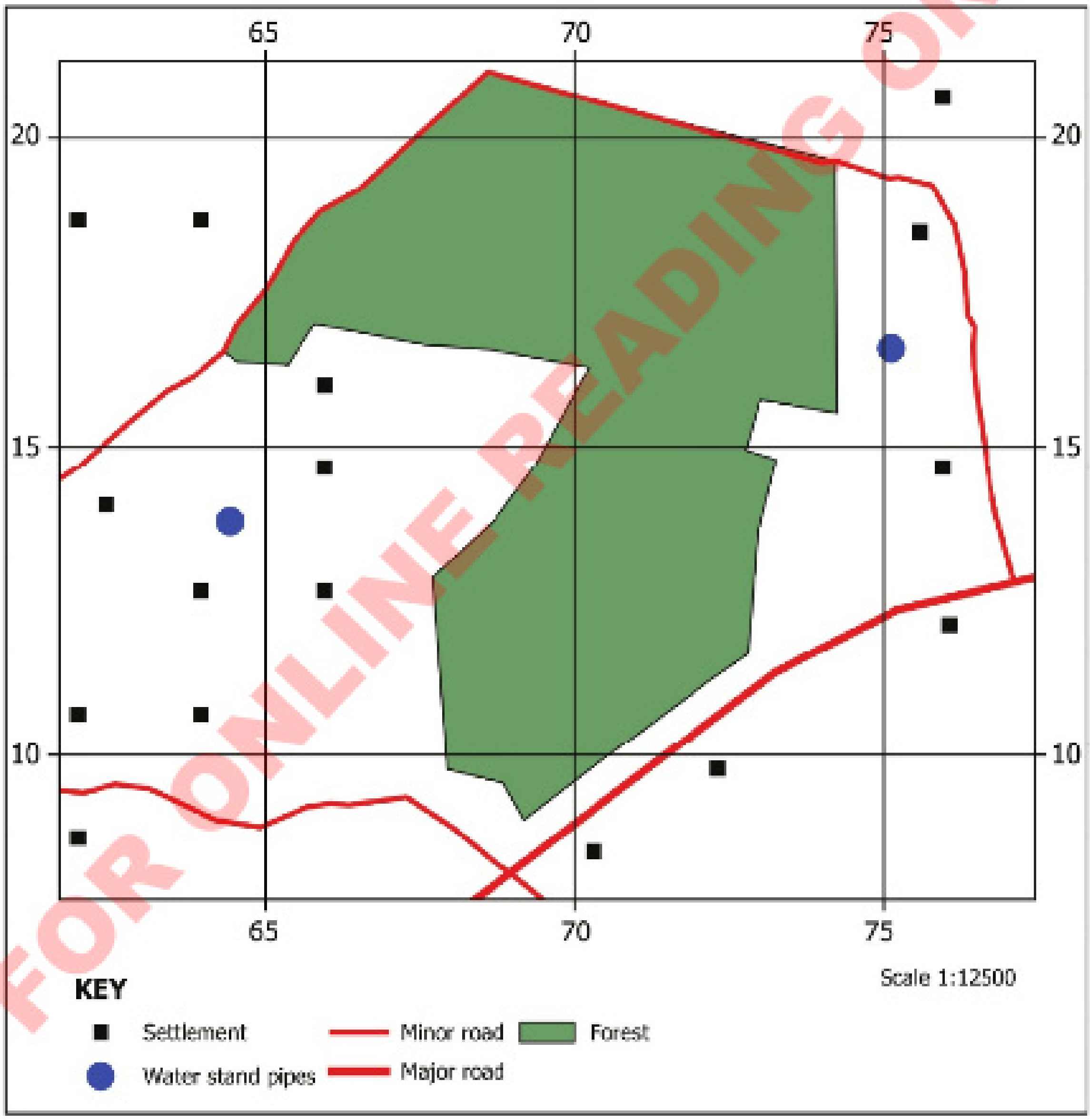
$$= \frac{1}{12\,500} \times \frac{25\,000}{1} = 2$$

Finding the new dimensions:

New side of a grid = Old side × Scale factor
= 2 cm × 2
= 4 cm

New width = Old width × Scale factor
= 6.3 cm × 2
= 12.6 cm

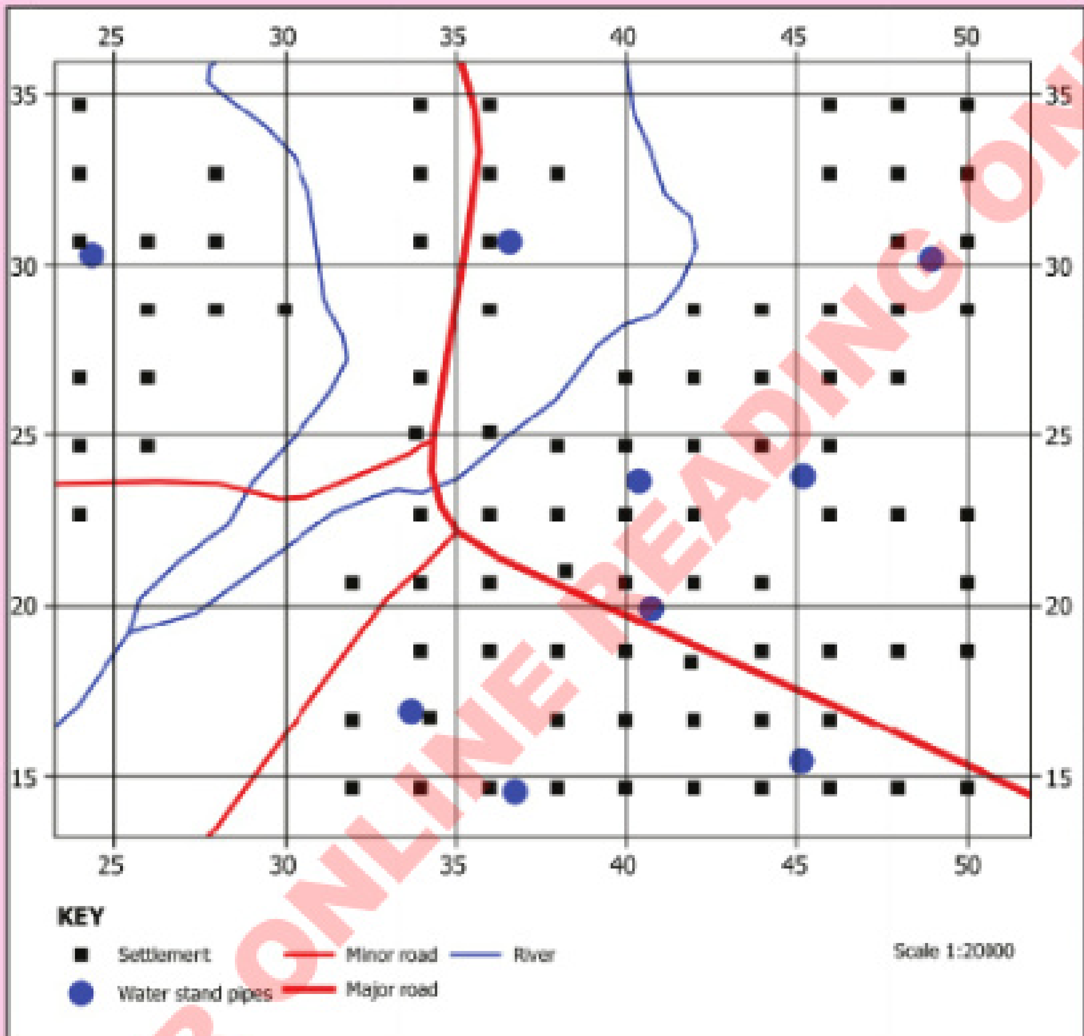
New length = Old length × Scale factor
= 5.5 cm × 2
= 11cm



Exercise 5.4

1. Analyse three effects that are likely to occur when the map is reduced or enlarged.
2. Study the hypothetical map of area X and redraw it by using the scale of 1:10000.

Hypothetical map of area X



Determining locations and directions of places

Location, direction and distance are everyday ways of assessing the space around us and identifying positions in different features relative to each other. They are also very basic in understanding the processes of spatial interaction that are important in the study of both physical and human geography.

Location

Location can be classified in two different ways that are absolute and relative locations.

Absolute location

Absolute location, also known as mathematical location, is the identification of a place by some precise and accepted system of coordinates. There are several such accepted systems of pinpointing positions, for example, global grid of parallels and meridians, that is, latitudes and longitudes. Absolute location is unique to a specific place and it is independent of any other characteristics or observation.

Geographers remark location of features a lot although their reference is usually not absolute but relative. Locations that is, the position of a place or things in relation to that of other place or things expresses spatial interconnection.

Relative location

Relative location tells us that people, things and places exist in the world of physical and cultural characteristics that differ from one place to another. In reality, when geographers talk of location, they refer to the physical and cultural characteristics like climate, soil, minerals, and attributes of the place itself.

Direction

This is another important aspect in geography. It is also expressed in absolute or relative terms. Absolute direction is based on the cardinal points of North, South, East and West. Relative direction refers to "far West" or far East.

Distance links location and directions

Distance is also divided into absolute and relative sense. Absolute distance refers to the spatial separations between two points on the earth's surface, measured by some accepted standard units such as miles or kilometres. Relative distance transforms those linear measurements into other units more meaningful for spatial relationship.

Fixing or locating positions on maps

Fixing or locating a position on maps is an important aspect in map reading. A person is able to identify a place after the position has been fixed and located. The position and direction of the place on the earth's surface and on maps can be expressed in various ways such as the use of place names, latitudes and longitudes, grid reference systems and bearing.

Place names

Places in topographical maps are identified and located by the name of the particular area. For example, in the map of Tanzania, different regions can be identified by their names such as Arusha, Dodoma, Shinyanga and Iringa (Figure 5.9).

Latitude and longitude

These are West-East and North-South angular distances on the earth's surface. They are the traditional and mostly used geographical ways in locating the position of features on the earth's surface. Most topographical maps indicate latitudes and longitudes along their edges, so as to give their respective location on the earth's surface although not all maps show these divisions in detail. Therefore, by means of these lines, one can identify the exact location of a feature on the mapped area.

In reading the latitudes and longitudes, start with latitudes then longitudes. For example, Dare es Salaam region is located at 6° 48'S and 39° 12'E. Latitudes and longitudes in maps are important for locating places precisely whereby two reference lines are needed and adopted on the uniform basis by all countries in order to avoid confusion. Using latitude and longitude, we can know how far an area is from the Equator and Prime Meridian, respectively. Also, latitudes are very important in characterizing the climate of the mapped area.

Figure 5.9: *A map of Tanzania locating position by place naming*

Grid reference system

A grid system is a pattern of horizontal and vertical lines of uniform sizes which are drawn on a map. The vertical lines are called eastings since their values increases eastwards from the grid origin while horizontal lines are called northings since their values increases northwards. Grid reference system depends on the type of projection used to prepare the map. For example, in Africa, the grid systems are based on the Universal Transverse Mercator (UTM) projection which divides the entire world into 60 zones. Within each zone, coordinates are measured as northings and eastings values in meters. These lines are essential for fixing position. The reading in a grid system is referred to as grid references and is provided in a six-digit number in which the first three digits are eastings and the last three digits are northings. For example, the position of point A in Figure 5.10 is 280610.

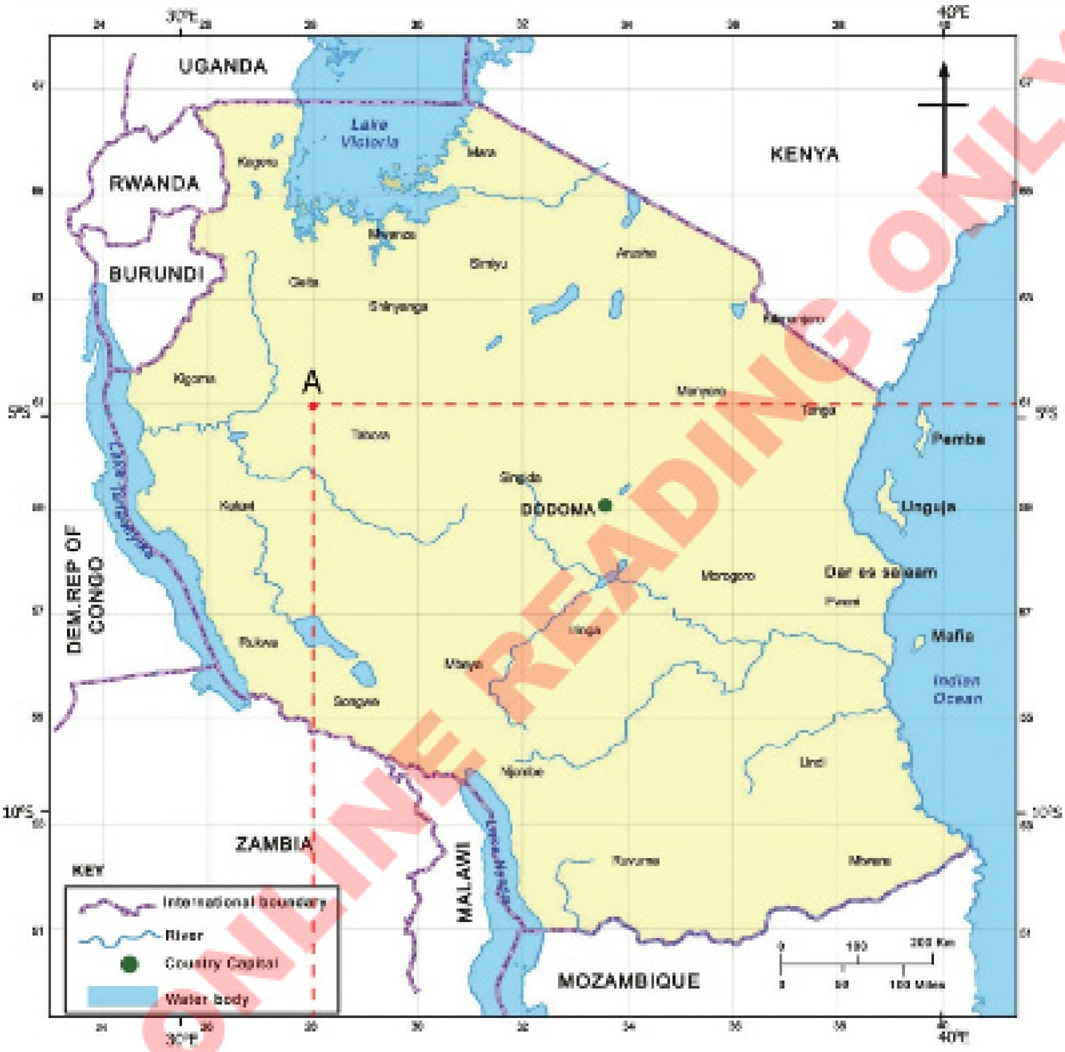


Figure 5.10: *Locating position by grid reference*

Bearing and direction

This is another way of fixing position or showing geographical position on the map. The compass bearing can be measured by using a compass. A compass is an instrument used to find direction and bearing. It consists of a free-swinging magnetic needle which can pivot to align itself with the magnetic north. If the local variation between the magnetic north and the true north is known then the direction of the magnetic north gives the direction of the true north. Compass bearing can be explained along the points such as compass direction, bearing of compass, direction of a place (trend and alignment) and North direction.

Compass directions are measured from North 000° to 360° of a circle clockwise. It is the bearing which determines the direction. For example, when the measured bearing is 45°, then the direction is North East; when the bearing is 90°, then its direction is East. The directions are divided into three categories which are the four cardinal points, the eight cardinal points and the sixteen cardinal points as shown in Figure 5.11.

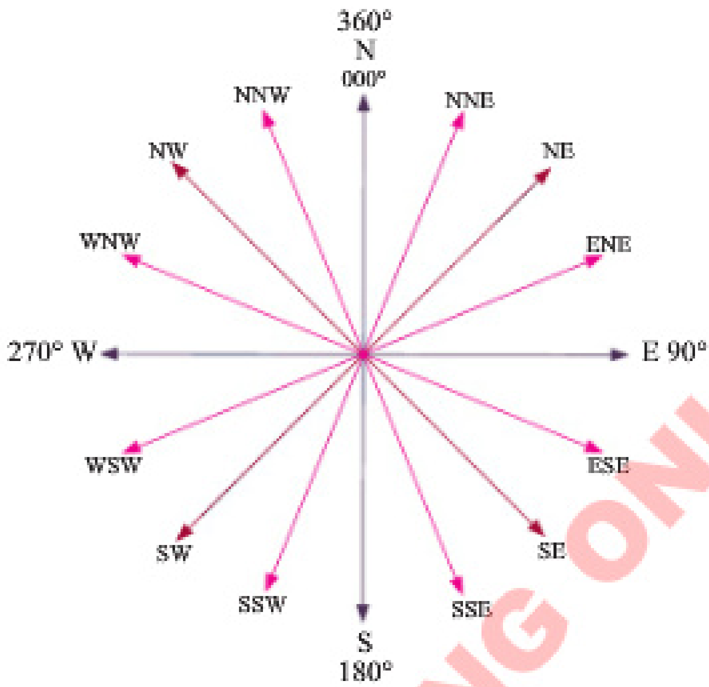


Figure 5.11: *Sixteen cardinal points*

Bearing of a compass shows the direction of point with respect to another point measured clockwise from 000° to 360°. Bearing is expressed in degrees, which are further subdivided into minutes and seconds.

Calculation of bearing

There are two types of bearings, namely:

(a) Forward bearing (FB)
(b) Back bearing (BB)

Forward bearing (FB)

This is the degree measured from an observer to the object along the line of sight or the degree reading to an object in front of the observer along the line of sight, with reference to the earth's magnetic north pole. An observer can check FB's accuracy by taking BB from the object to his former position.

Procedures of measuring bearing

(i) Identify the two points.

(ii) Join the two points with a straight line. For example, from grid reference A to grid reference B (Figure 5.12).

(iii) At one point, either A or B (depending on the question asked), draw a line parallel to the North direction or grid vertical lines.

(iv) Using a protractor, measure the angle or bearing at point A or B depending on the question.

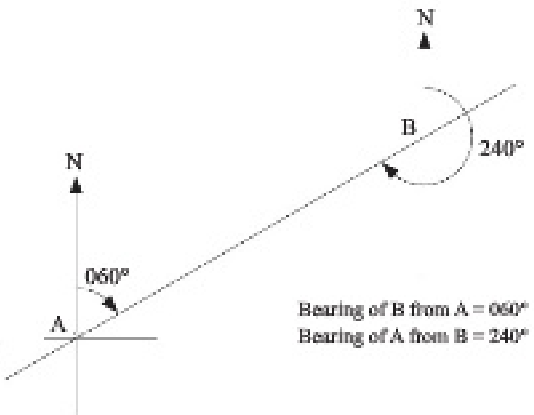


Figure 5.12: *Forward and back bearing*

Back bearing (BB)

This is the degree measured from an object to the observer along the line of sight. The rule is that, if the FB is greater than 180°, then subtract 180° from the FB to obtain BB. This implies that BB = FB -180°. If the FB is less than 180°, then add 180° to the forward bearing to get BB. This implies that BB = FB + 180°.

Forward and back bearing from one point to the next on the given map can be revealed by a application of parallel lines and angles of transverse. This rule provides a map reader with pairs of corresponding angles and pairs of vertical opposite.

FB of 'A' to 'B' is the same as FB of 'B' from 'A' = 60°

FB of ' B' to ' A' is the same as FB of 'A' from B = 240°

FB of 'B' from 'A' is equal to 'BB' of 'A' from B = 60°

FB of 'A' from ' B' is equal to BB of 'B' from A = 240°

The significance of backward bearing

Backward bearing is useful for checking the accuracy of forward bearing reading as taken from the observer to the object along the line of sight. The accuracy is normally checked by identifying the difference in degrees between the forward and backward bearing. The difference between backward bearing and forward bearing is normally 180°. If the difference appears to be less or greater than 180°, it shows that forward, backward or both bearings are not correct. It indicates the presence of errors which may be caused by different factors during surveying. The errors are corrected by mean error method using the following procedures.

(i) Identify the two bearings (forward and back bearings);

(ii) Find the difference between the two bearings, for example (FB-BB);

(iii) Determine the amount of error. Amount of error = difference in (ii) – 180°;

(iv Find the mean error. Mean error = amount of error in (iii) divide by two;

(v) Subtract the mean error from the reading with a large value then add the mean error to the reading with a small value; and

(vi) Prove the reading. When proving the reading, FB – BB or BB –FB = 180°.

Example

A prismatic compass surveyor recorded forward bearing as 68° and its back bearing 250°. Correct the discrepancy of these readings.

Solution

Data given

$FB = 68°$

$BB = 250°$

Procedures

(i) Find the difference between BB and FB.

BB – FB = 180°

250° – 68° = 182°

Difference = 182°

The difference (D) is above 180°, implying presence of a positive error.

(ii) Determine amount of errors.

Amount of error = Difference – 180°

182° – 180° = 2°

(iii) Find the mean error.

$$\text{Mean error} = \frac{Error}{2}$$

$$= \frac{2}{2} = 1°$$

Mean error = 1°

(iv) Subtract the mean error from the reading with a large value then add the mean error to the reading with a small value.

$BB_1 = BB_0 - 1°$

$= 250° - 1°$

$= 249°$

$FB_1 = FB_0 + 1°$

$= 68° + 1°$

$= 69°$

$FB_1 = 69°$

(v) Prove the readings.

$BB - FB = 180°$

$249° - 69° = 180°$

Therefore, the correct readings are:

$BB_1 = 249°$

$FB_1 = 69°$

Example

Correct the discrepancy if the forward and back bearings are 254° and 75° respectively.

Solution

Data given

$FB_0 = 254°$ $FB_1 = ?$

$BB_0 = 75°$ $BB_1 = ?$

Procedures

(i) Find the difference between FB and BB.

$FB - BB = 180°$

$254° - 75° = 179°$

The difference (D) is below 180°, implying presence of a negative error.

(ii) Determine the amount of error.

Amount of error = D – 180°

$= 179° - 180°$

$= -1°$

(iii) Find the mean error $= \frac{\text{Error}}{2}$

$$= \frac{-1}{2}$$

$$= \frac{-1}{2} = -0.5$$

Mean error = – 0.5°

(iv) Add the mean error to the reading with a small value and subtract mean error from the reading with a large value.

$BB_1 = BB_0$ + Mean error

$BB_1 = 75° + (-0.5°)$

$BB_1 = 74.5°$

$FB_1 = FB_0$ − Mean error

$FB_1 = 254° - (-0.5°)$

$FB_1 = 254° + 0.5°$

$FB_1 = 254.5°$

(v) Prove the readings.

$FB_1 - BB_1 = 180°$

$254.5° - 74.5° = 180°$

Therefore, the correct readings are:

$FB_1 = 254.5°$

$BB_1 = 74.5°$

Example

Detect errors and correct, if any, in the following forward and backward bearings as recorded by a surveyor.
FB = 249°, BB = 66°, FB_1 = ? BB_1 = ?

Solution

Data given

FB = 249°

BB = 66°

Procedures

(i) Find the difference between the FB and BB.

$FB_0 - BB_0$

$= 249° - 66°$

$= 183°$

Difference = 183°

The difference (D) is above 180°, implying of positive error.

(ii) Determine amount of error.

Amount of error $= D - 180°$

$= 183° - 180° = 3°$

(iii) Find the mean error $= \frac{\text{Error}}{2}$

$= \frac{3°}{2} = 1.5°$

(iv) Add the mean error to the reading with a small value and subtract mean error from the reading with a large value.

$BB_1 = BB_0$ + Mean error

$= 66° + 1.5°$

$= 67.5°$

$BB_1 = 67.5°$

$FB_1 = FB_0$ − Mean error

$= 249° - 1.5°$

$= 247.5°$

$FB_1 = 247.5°$

(v) Prove the readings.

$FB_1 - BB_1 = 180°$

$247.5° - 67.5° = 180°$

Therefore, the correct readings are:

$FB_1 = 67.5°$

$BB_1 = 247.5°$

Exercise 5.5

1. An amateur surveyor reads forward bearing as 265° and backward bearing as 80°. Correct the discrepancy.
2. The headmaster's office is located at the centre of the school compound. The bearing measured by Fatma from the headmaster's

office to the library was 320°, but Mr Azwar measured the bearing of 144° from the library to the headmaster's office. Correct the discrepancy of their measurements.

Fixing position of an object on the map by intersection and resection methods

Bearing and direction as the method of, among others, locating position, is the basis for intersection and resection methods.

Intersection method

Intersection method is a method of fixing unknown position of an object on the map by taking bearings to it from two or more fixed points. Intersection involves more than one observer at fixed positions and only one object at the unknown position. In this method, forward bearings are used but not changed into back bearing. It is the simplest method of identifying the position of an object compared to resection.

When the two forward bearing measures at known positions are provided, it is possible to locate the position of the unknown point or the object, by fixing the positions of the given points and taking the bearings towards the unknown point as directed by the bearing method.

Using intersection method, the position of an object or location on a map is fixed or found using the following procedures:

(i) Using grid references, mark the position of the two known locations (towns);

(ii) Draw the line parallel to the north direction at the position of both known positions;

(iii) Using a protractor, measure the FB from the two parallel lines at the two known positions;

(iv) Draw straight lines from each point along the measured angle; and

(v) Read the grid reference location where the two lines intersect.

Example

Suppose the forward bearings from Dar es Salaam and Morogoro to Arusha were 353° and 22°30', respectively. If the grid reference of Morogoro and Dar es Salaam in Figure 5.13 are 516224 and 556225 respectively, find the position of Arusha by intersection method.

Procedures

(i) Using grid references, mark the position of Dar es salaam and Morogoro on the map;

(ii) Draw the line parallel to the north direction at the position of both Dar es Salaam and Morogoro;

(iii) Using a protractor, measure the FB of 353° and 22°30' from the two parallel lines at Dar es Salaam and Morogoro;

(iv) Draw straight lines from each point along the measured angles;

(v) Read the grid reference location where the two lines intersect. The grid reference at the point where lines intersect is the coordinate of Arusha.

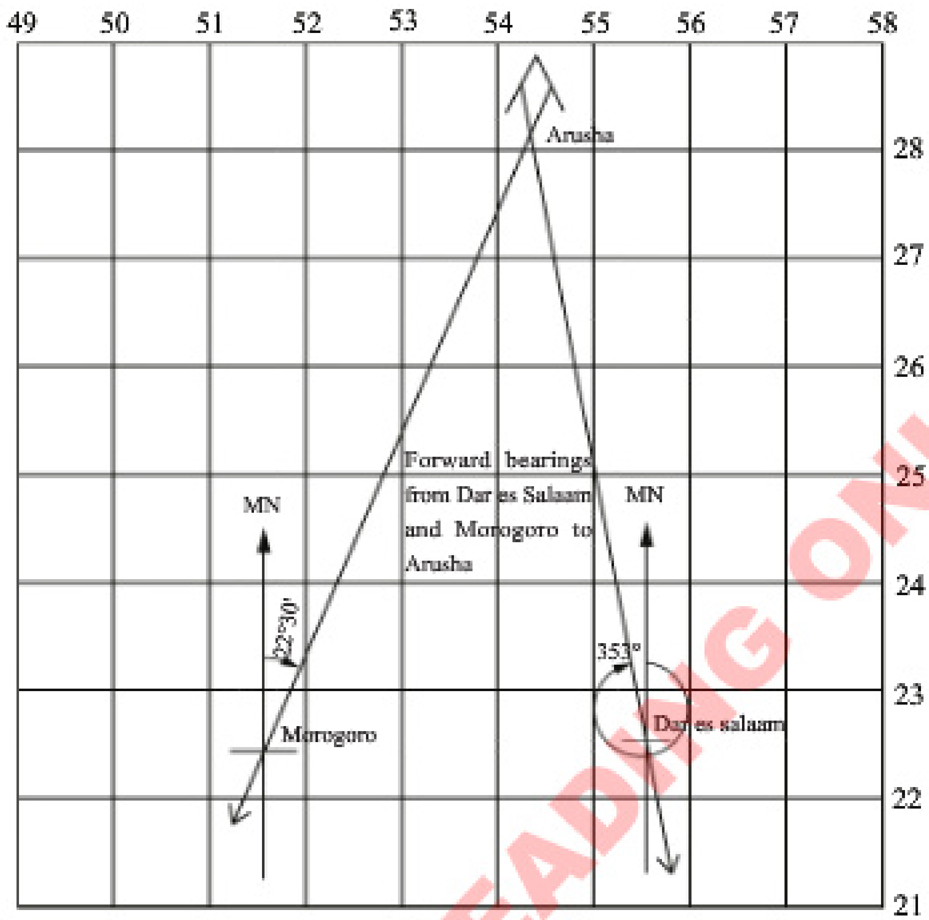


Figure 5.13: *Intersection of points*

Therefore, Arusha is located at grid reference 543282.

Resection method

Resection method identifies the location of the unknown object by taking the bearings from it to two or more known points located on the map. The readings are converted to back bearings and angle lines drawn from the points to meet at the observer's position. It involves only one observer who is at the unknown position, viewing more than one object at the same time.

Procedures

(i) Identify and mark the location of each object by using grid reference;

(ii) Measure forward bearing from an object of unknown position to two or more objects of known position;

(iii) Change the forward bearings to back bearings;

(iv) Establish the cardinal points by drawing lines parallel to the vertical grid at each marked object's position;

(v) Using the protractor, measure the back bearing from parallel lines at each marked objects; and

(vi) Draw the straight lines along the measured bearings. The observer's location is the point where the two lines cross each other.

Example

Ms Audrey observed a feature 'x' at grid reference 040160 from a bearing of 45°and feature 'y' at grid reference 060115 from a bearing of 135°. Locate the position of Ms Audrey.

Solution

(i) Mark the position of point X and Y on the map as shown in Figure 5.14;

(ii) Find the back bearing from X and Y to Audrey's position;
$BB_{XA} = 45° + 180° = 225°$
$BB_{YA} = 135° + 180° = 315°$

(iii) Draw vertical lines at X and Y as shown in Figure 5.14 to define North direction;

(iv) Using a protractor, measure the BB of 225° and 315°from vertical lines at points X and Y; and

(v) The point where the two lines intersect is Audrey's position.

Changing the forward to back bearings
$BB = FB \pm 180°$

From X 45° + 180° = 225°
From Y 135° + 180° = 315°

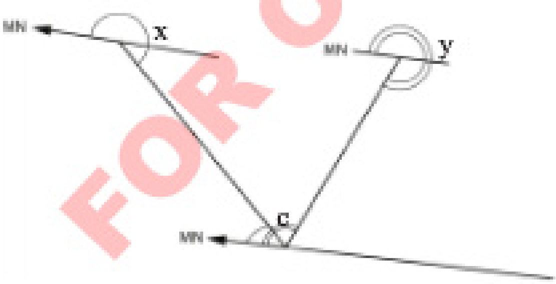


Figure 5.14: *Plotting point C by resection using back bearing of x and y*

Trend and alignment

Trend, also known as direction of place, is a general layout of elongated features such as a river, valley, coastline, railway or road. Trend is expressed in degrees. Usually, trend is given in compass bearings and the bearings are used to determine the direction. It helps the map user to know the general layout of features and extent of the general curvature. The procedures for measuring trends are as follows:

(i) Identify the two points;

(ii) Join the two points with a straight line;

(iii) Note the middle point of the line;

(iv) Draw the North direction on the noted point (middle point); and

(v) Measure the angles and give their degrees.

Trend involves two angles. The first bearing is measured from the North direction clockwise until it touches the drawn line that joins the two points. The second bearing is drawn in the same ways, but it crosses the drawn line and touches it in the second part as shown in Figure 5.15. The first angle is the FB where the second one is the BB.

If the first angle is well measured, the second angle is given by the use of a mathematical formula. For example, if the first bearing in Figure 5.15 is 55°, then:

$x° = Y° + 180°$

$x° = 55° + 180°$

$x° = 235°$

Note that, the correct second bearing will be obtained only if the first bearing is properly measured. Trend is 55° to 235°.

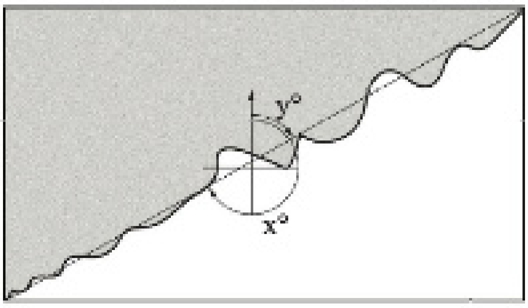


Figure 5.15: *Trend of a coastline*

Alignment is a general direction of elongated features such as a ridge and a coastline. Usually, alignment is stated using the direction in which the feature lies. The same procedures of determining trend are used to determine alignment. But in alignment, the measured angles are used to describe the general direction of the feature involved. For example, if the trend of the feature is 55° to 235° as shown in Figure 5.28, its alignment is NE to SW. From the illustration above, trend and alignment can be stated in a general form as 55° NE to 235° SW.

NB: The best way of showing trend or alignment is by using both bearing and direction.

Types of North directions

The North direction on a map can be shown by using different types of north. These are True North (TN), Magnetic North (MN) and Grid North (GN) (Figure 5.16).

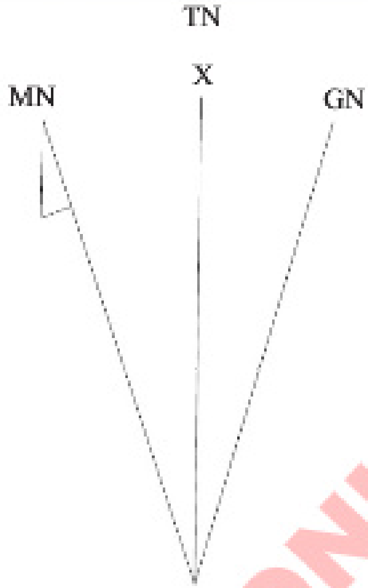


Figure 5.16: *The types of North direction*

True North

This is the type of north direction in which all meridians or longitudes converge in the northern hemisphere. Its direction is towards the 000° North from any place on the earth's surface. It is very near to the point at which the rotation axis of the Earth passes through. It is shown on the map by a star headed line. TN is also called geographical North Pole and it is always fixed. The angle measured clockwise from geographical north to the object along the line of sight is called true bearing.

Magnetic North

This is a direction indicated by the freely suspended magnetic needle. Magnetic North is the line representing the direction of the needle of a magnetic compass pointing when the map was published. MN enables to obtain the magnetic bearing. It is the point in northern Canada where lines of the earth's magnetic fields intersect. MN is naturally a migratory point caused by the shifting behaviour of the earth's magnetic field which is influenced by a number of factors including the earth's rotation and ionisation of the liquid metal in the outer core. This is called polar shift theory, as the world is not static, but dynamic. The Earth changes every day, plate tectonics push continents apart, sea levels fluctuate up and down, volcanic eruption discharge ash and smoke on the surface, denudation occurs and climate changes.

A Magnetic bearing is the angle at which the line from the observer's position to the object meets with the line pointing in the direction of the magnetic north. The angle measured clockwise from the magnetic north to the object through the line of sight is called magnetic bearing.

Grid North

Grid north is the direction towards the north in maps drawn by grid system. Grid north is a direction that is parallel to the easting lines found on the Universal Transverse Mercator (UTM) grid system. The grid north aids in obtaining a topographical map since it is used as a baseline of clockwise direction. GN is shown by a bare line.

Magnetic variation

Magnetic North and the True North never coincide. They normally leave a gap apart which always changes with time due to the shifting tendency of the magnetic influence. Therefore, magnetic variation is the angular distance between the Magnetic North and the True North, which usually keeps on changing with time and space. The decrease and the increase of the angle depends on the position of the Magnetic North in relation to the True North. Magnetic North keeps on changing its position at a specific rate with time in relation to the position of the True North. It may be located in the western or eastern part of the True North which never changes its position. However, in the African continent, Magnetic North is located to the west of the True North. Determination of magnetic variation depends on the position of MN in relation to the TN.

Principles governing calculations of magnetic variation, magnetic bearing and true bearing when the magnetic north is to the west of the True North.

As shown in Figure 5.17, the position of the Magnetic North is west of the True North. The gap between Magnetic North and True North denoted by MV_1 is the initial angle recorded before the change in position of the Magnetic North. As the Magnetic North started to shift eastward, slowly, the gap started to become smaller with time, giving the second angle in between denoted by MV_2. The angle between the new position and old position of the Magnetic North is called total change (TC). The observation made from the Figure 5.17 therefore establishes that: *when the Magnetic North is in the West of the True North and the rate of annual change is eastward, the final magnetic variation is the difference between the initial magnetic variation and the total change (TC).*

$MV_2 = MV_1 - TC_1$

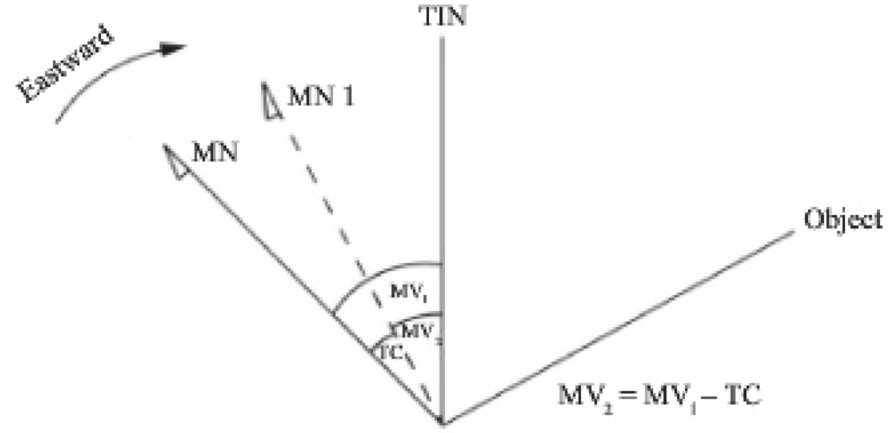


Figure 5.17: *Annual change of magnetic variation from eastward*

Example

Find the magnetic variation of town X in March 2020, if in September 2010 its magnetic variation was 20°10'05" W and the rate of change stood at 10' eastward per year.

Solution

$MV_2 = MV_1 - TC$

Data given

$MV_1 = 20°\ 10'\ 05"$

$T_2 =$ Year Month
2020 3

$T_1 =$ Year Month
2010 9

Rate = 10' E

$TC = ?$

$MV_2 = ?$

Find the difference in time

$T_2 - T_1$

Years	Months
2020	03
− 2010	09
09	06

$= 9\frac{1}{2}$ years

Find the total change.

If 1 year = 10' E

$9\frac{1}{2}$ years = ?

$\frac{9.5 \times 10}{1} = 95'$ E

Remember: 1° = 60' and 1' = 60"

Therefore, 95' E=1°35'00" E

Total change =1°35'00" E

New magnetic variation

$MV_2 = MV_1 - TC$

$MV_2 = 20°10'05" - 1°35'00" = 18°35'05"$

Therefore, magnetic variation of town X in March 2020 was 18°35'05" W.

If you carefully study Figure 5.18, you will note that the diagram represents an idea bit opposite to the first diagram. The arrow pointed in solid line marks the initial position of the Magnetic North (MN) separated by a narrow angular distance from the True North (TN), denoted as MV_1. Slowly, the narrow angular distance started to widen as the Magnetic North (MN) shifted westward into the new position indicated by the dotted arrow-pointed line MN_1. Then the new wider angle denoted as MV_2 exists between the new position of the Magnetic North and the True North. Similarly, the narrow angle denoted as TC is between the new and the old position of the Magnetic North. This can generally be concluded that, when the position of the Magnetic North is in the West of the True North, and the rate of annual change is westward, the final magnetic variation is the sum of the initial magnetic variation and the total change.

$MV_2 = MV_1 + TC$

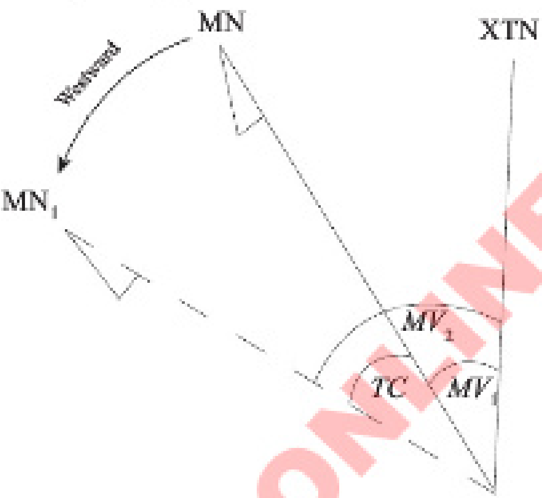


Figure 5.18: *Annual change of Magnetic variation from westward*

Example

Find the magnetic variation of town X in March 2020, if in September 2010 its magnetic variation was 20°10'05"W and the rate of change stood at 10' westward per year.

Solution

$MV_2 = MV_1 + TC$

Data given

$MV_1 = 20°\ 10'\ 05''$

T_2 = Years Months
2020 03

T_1 = Years Months
2010 09

Rate = 10'W

$TC = ?$

$MV_2 = ?$

Find the difference in time.

$T_2 - T_1$

Years	Months
2020	03
− 2010	09
09	06

$= 9\frac{1}{2}$ years

Find the total change.

Then, if

1 Year = 10' W

$9\frac{1}{2}$ Years = ?

$\frac{9.5 \times 10}{1} = 95'$ W

Remember: 1° = 60' and 1' = 60"

Therefore, 95' W= 1°35' 00"

Total change = 1°35' 00" W

New magnetic variation

$MV_2 = MV_1 + TC$

$MV_2 = 20°10'\ 05'' + 1°35'\ 00'' = 21°45'05''$

Therefore, magnetic variation of town X in March 2020 was 21°45'05" W.

Rules governing calculations of magnetic variation, magnetic bearing and true bearing when the magnetic north is in the East of the true north

As shown in Figure 5.19, the position of the Magnetic North is in the East of the True North. The gap between magnetic north and the true north denoted by MV_2 is the initial angle recorded before the change in position of magnetic north. As the Magnetic North started to shift eastward, slowly the gape started to become larger with time, giving the new wider angle denoted as MV_1. The angle between the new and old position of the Magnetic North is called total change. From the observation made in Figure 5.18, it can be deduced that: when the *Magnetic North is in the East of the True North and the rate of annual change is eastward, the final magnetic variation is the sum of initial magnetic variation and the total change. Mathematically given a:*

$MV_2 = MV_1 + TC$

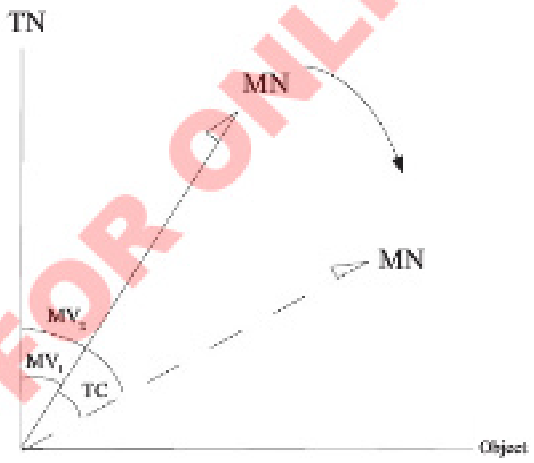


Figure 5.19: *Annual change of magnetic variation from eastward*

Example

Determine the magnetic variation of Mafia Island in April 2025 if its magnetic variation in September 2010 was 15°30'12" E and the rate of change is 8' eastwards per year.

Solution

$MV_2 = MV_1 + TC$

Data given

MV_1=15°30'12"

Rate of change = 8′ E

T_2= Years Months
2025 04

T_1= Years Months
2010 09

TC = ?

MV_2 = ?

Find the difference in time.

$T_2 - T_1$

Years	Months
2025	04
− 2010	09
14	07

$= 14\frac{7}{12}$ years

= 14.58 years

If 1 year = 8'

14.58 = ?

$= \frac{14.58 \times 8'}{1}$

=116.64' E

Remember: 1° = 60' and 1' = 60"

Therefore,=116.64' E = 1°56'38"

Total change = 1°56'38" E

New magnetic variation

$MV_2 = MV_1 + TC$

$= 15°30'12" + 1°56'38"$

$= 17°26'50"$ E

Therefore, magnetic variation of Mafia Island in April, 2025 will be 17°26'50" E.

As shown in the Figure 5.20, the position of Magnetic North is still in the East of the True North. The gap between the Magnetic North and the True North denoted by MV_1 is the initial angle recorded before the change in position of the Magnetic North. As the Magnetic North started to shift westward, slowly the gap started to become smaller and smaller with time giving the new narrow angle in between denoted as MV_2. The angle between the new position and the old position of the Magnetic North is called total change (TC). Generally, it can be deduced that, *when the magnetic north is in the East of the true north and the rate of annual change is westward, the final magnetic variation is the difference of initial magnetic variation and the total change.*

$MV_2 = MV_1 - TC$

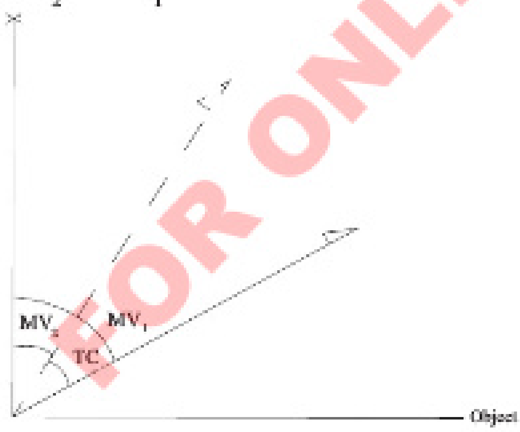


Figure 5.20: *Annual change of magnetic variation from westward*

Example

Find the magnetic variation of town X in March 2020, if in September 2010 its magnetic variation was 20° 10' 05" E and the rate of change stood at 10' westward per year.

Solution

$MV_2 = MV_1 - TC$

Data given

$MV_1 = 20°10'05"$

	Years	Months
T_2 =	2020	03
T_1 =	2010	09

Rate = 10' W

$TC = ?$

$MV_2 = ?$

Find the difference in time.

$T_2 - T_1$

Years	Months
2020	03
− 2010	09
09	06

$= 9\frac{1}{2}$ years

Find the total change.

Then, if

1year = 10' W

$9\frac{1}{2}$ years = ?

$\frac{9.5 \times 10'}{1} = 95'W$

Remember: 1° = 60' and 1' = 60"

Therefore, 95' W = 1° 35' 00"

Total change = 1° 35' 00" W

New magnetic variation

$MV_2 = MV_1 - TC$

$MV_2 = 20°\ 10'\ 05'' - 1°\ 35'\ 00''$

$= 18°\ 35'\ 05''$ E

Therefore, the magnetic variation of town X in March 2020 was 18° 35' 05" E.

The following are rules governing calculation of true bearing, if the magnetic bearing of an object from its observer is given:

(a) When the magnetic declination is in the West of the True North as shown in Figure 5.21, subtract magnetic declination or magnetic variation (MV) from the magnetic bearing (MB) to obtain the True Bearing (TB).

That is, TB = MB – MV and MB = TB + MV.

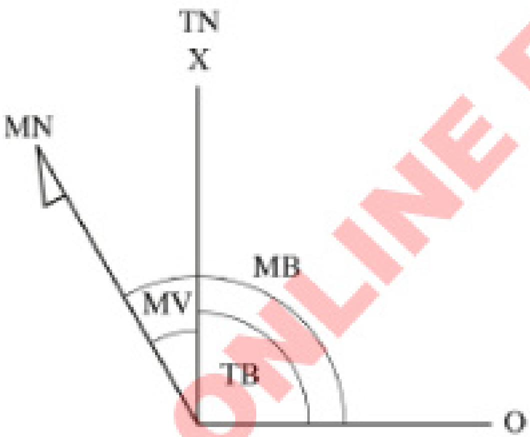


Figure 5.21: *West declination of MN*

(b) When the Magnetic North is in the East of the True North as shown in Figure 5.22, add Magnetic declination or Magnetic variation (MV) to magnetic bearing (MB) to obtain the True Bearing. That is, TB = MB + MV and MB =TB – MV.

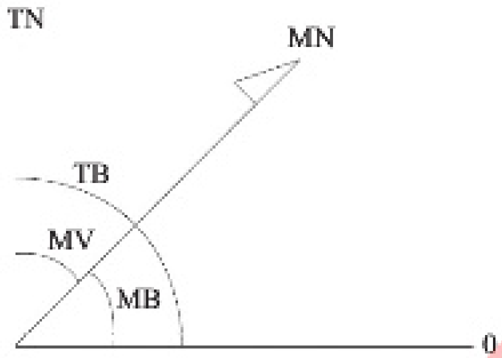


Figure 5.22: *East declination of MN*

When magnetic variation changes, magnetic bearing changes as well, but true bearing remains constant.

Example

True Bearing and Magnetic Bearing of Mbuyuni village in September 2010 were 120°35' 25" and 75°30' 36" respectively. Determine its magnetic declination and Magnetic Bearing in May 2020, if the rate of change was 20' W, given that Magnetic North is declined to the East.

Solution

$MV_2 = MV_1 - TC$ and $MV_1 = TB - MB$

Data given

T_1 = Years Months
2010 09

T_2 = Years Months
2020 05

Rate = 20' W

Determine the position of MN.

If $MB < TB$, it means that MN is in the East of TN

Rate of change

$T_2 - T_1$

Year	Month
2020	09
− 2010	05
09	08

= 9.67 years

Find total change

If 1 year = 20'

9.67 years = ?

$= \frac{9.67 \text{ years} \times 20'}{1 \text{year}}$

= 193.4' W

Remember: 1° = 60' and 1' = 60"

Therefore, 193.4' W = 3°13'24"

Total change 3°13'24" W

$MV_2 = MV_1 - TC$

$MV_1 = \text{TB} - \text{MB}$

Thus,

$MV_1 = 120°\,35'\,25" - 75°\,30'\,36"$

$MV_1 = 45°04'49"$

From

$\text{MV}_2 = MV_1 - TC$

$\text{MV}_2\ 45°\,04'\,49" - 03°\,13'\,24"$

= 41°51'25"

Then,

$\text{MB}_2 = \text{TB} - \text{MV}_2$

$\text{MB}_2 = 120°\,35'\,25" - 41°51'25"$

$\text{MB}_2 = 78°44'00"$

Therefore, magnetic variation and magnetic bearings at Mbuyuni village in May 2020 were 41°51'25" E and 78°44'00" *respectively.*

Example 2

Magnetic variation of town Y by October 2012 and December 2021 were 45°30'05" E and 36°50'09" E respectively, while Magnetic Bearing was 85°45'35" by October 2021.

(i) Determine the annual rate of change.

(ii) Compute Magnetic Bearing and True Bearing in December 2021.

Solution

Data given

Magnetic Variation$_1$ (MV_1) = 45°30'05"

Magnetic Variation$_2$ (MV_2) = 36°50'05"

Magnetic Bearing$_1$ (MB_1) = 85°45'35"

T_1 = Years Months

2012 10

T_2 = Years Months

2021 12

Rate of change (R) = ?

MB_2 = ?

Old TB = ?

Find change in time (t)

$T_2 - T_1$

Year	Month
2021	12
− 2012	10
9	2

$= 9\frac{2}{12}$ years

Time interval = 9.17 years

Since both old and new magnetic variations are given with Eastern directions, magnetic north is in the east of true north. Further, the direction of annual change is westward since old magnetic variation (MV_1) is greater than new magnetic variation (MV_2).

$MV_2 = MV_1 - TC$

Then,

$TC = MV_1 - MV_2$

$= 45°30'05' - 36°50'09''$

$= 8°39'59'' \approx 519.98'$

Total change = 519.98'

To find magnetic variation, if

9.17years = 519.98'

1year = ?

$\frac{1year \times 519.98}{9.17years}$

= 56.7'

= 56.7' = westward

The annual bearing in 2021 December (MB_2)

$TB = MB + MV$

Remember; MV is to the East of TN

$TB = MB_1 + MV_1$ or $= MB_2 + MV_2$

Note: When Magnetic Variation changes, Magnetic bearing changes as well, but True Bearing remains constant.

Then, $TB = MB_1 + MV_1$

= 85°45'35"
+ 45°30'05"
131°15'40"

TB = 131°15'40"

$MB_2 = TB_1 - MV_1$

= 131°15'40"
− 36°50'09"
94°25'31"

New Magnetic Bearing in 2021 (MB_2) = 94°25'31"

Example

Given that Magnetic Bearing of town Y was 248°05'00" and magnetic variation was 15°26'00", find the true bearing of the town Y.

Solution

Data given

MB = 248°05'00"

MV = 15°26'00"

$MB = MV + TB$

$MB - MV = TB$

When the magnetic declination is to the East of the True North, add the magnetic declination to the magnetic bearing to obtain the True Bearing. Thus means, if variation was 15° 26' 00".

Solution

$TB = MV + MB$

= 15°26' + 232°29'

= 248°05'

Therefore, the True Bearing of the town Y is 248°05'.

Exercise 5.6

1. By March 2007, town Z located in West Africa had MB and TB of 45°23'12" and 250°34'57", respectively. If the rate of change was 15 minutes per annum negatively, calculate the following by September 2022:
   (b) Magnetic variation
   (c) True bearing
   (d) Magnetic bearing

2. Magnetic bearing of Kibo Hill in September 2010 was 120°35'25" while its TB was 75°30'36". Determine its magnetic variation in May 2020, if its annual rate of change was 20' eastward.

Using principles of map interpretation

The map interpretation principles apply the techniques of cross-cutting relationships. By mastering conventions and alphabets of a map, it becomes possible to spell out situations in the landscape from the association and relationships of symbols. In topographical maps, all the information about landscape, themes, cultural features and location and direction are depicted with the assistance of conventional signs and symbols. It should be noted that conventional signs and symbols are used to define the features represented on the map. Thus, they should be relevant to the actual features represented. They should also be common, familiar and widely accepted by map readers; otherwise, there will be misinterpretation of the information. One can read and interpret the position, climate, relief, vegetation, drainage, settlement, rocks and human activities shown on the map.

Extracting position of features or points

The use of latitudes and longitudes of an area studied will tell where the piece of land or features lies in the world. When one knows this, it becomes easy to picture out the chief geographical characteristics of the area by applying general knowledge of geography. In addition to that, latitude degree helps to determine hemispherical position (location) of the mapped area. If a latitude degree is followed by the letter 'S' it means it is taken from the Southern hemisphere while letter 'N' indicates the Northern hemisphere.

Therefore, it is possible to find the position of a piece of land or object on the earth surface by using latitudes and longitudes (graticule system).

Example

Calculate the longitude and latitude coordinates of Dodoma town which is found at grid reference 328590 in Figure 5.10. Start with 30° E and 05°S.

Solution

Longitude

(i) Find difference in degrees between longitudes 40° E and 30° E as

$$40° \text{ E} - 30° \text{ E} = 10° \text{ E}$$

(ii) Measure the map distance, say 14.8 cm, between longitudes 40° E and 30° E.

(iii) Measure the distance, say 8.2 cm, from longitudes 30° E to Dodoma.

(iv) Convert the distance measured in (iii) into angular units based on linear and angular relationships established in (i) and (ii). That is,

$$14.8 \text{ cm} = 10°$$

$$8.3 \text{ cm} = ?$$

$$= \frac{8.2 \text{ cm} \times 10°}{14.8 \text{ cm}}$$

$$= 5.54°$$

$$5.54° = 5° + 0.54°$$

$$1° = 60'$$

$$0.54° = ?$$

$$= \frac{0.54° \times 60'}{1°} = 32.4'$$

$$32.4' = 32' + 0.4'$$

$$1' = 60''$$

$$0.4' = ?$$

$$= \frac{0.4' \times 60''}{1'} = 24''$$

Therefore, $5.54° = 5°32''24''$

(v) To find the longitude of Dodoma, add the angular distance in (iv) to the longitude of 30° E.

Thus, 30°00'00" E
\+ 5°32'24"

35°32'24" E

Latitude

(i) Find difference in degrees between two latitudes, say 10°S and 5°S as follows:

$10° - 5° = 5°$

(ii) Measure the map distance, say 7.6 cm, between latitudes 10°S and 5°S.

(iii) Measure the distance, say 1.8cm from latitude 5°S to Dodoma.

(iv) Convert the distance measured in (iii) into angles based on the relationship established in (i) and (ii) that is,

$7.6 \text{ cm} = 5°$

$1.8 \text{ cm} = ?$

$$\frac{1.8 \text{ cm} \times 5°}{7.6 \text{ cm}} = 1.18°$$

$1.18° = 1° + 0.18°$

$1° = 60'$

$0.18° = ?$

$$= \frac{0.18° \times 60'}{1°} = 10.8'$$

$10.8' = 10' + 0.8'$

$1' = 60''$

$0.8' = ?$

$$= \frac{0.8' \times 60''}{1'} = 48''$$

$1.18° = 1° + 10' + 48''$

Therefore, $1.18° = 1°\ 10'\ 48''$

(v) To get the latitude of Dodoma, add the angular distance in (iv) to latitude 5°S as follows:

5°00'00" S
\+ 1°10'48"

6°10'48" S

Therefore, position of Dodoma town at grid reference 328590 lies at longitude 35° 32' 24" E and latitude 6° 10' 48" S.

Climate interpretation

A great deal of climatic information can be deduced from the topographical maps using latitude, drainage (water bodies), relief and vegetation as explained below.

Latitude

This is the most common hint used in the mapped area. It gives general indications concerning rainfall and mean annual temperature. For instance, areas between 0° to 5° north or south of the Equator fall under the equatorial climate. These areas are characterised by high temperature and high rainfall. Areas between 5° and 15° north or south of the Equator are in the category of tropical climate with moderate rainfall marked by wet and dry seasons and the temperature is also high. Areas between 15° and 35° north or south of the Equator are categorised as desert climate with very high temperature and little or non rainfall.

Altitude: the mean temperature decreases with altitude at an average rate of 6.5°C for every 1 000 m. Thus, if one notes the height of a place, they can make an easy arithmetic guess whether the area experiences high or low temperature. Rainfall type can also be determined by the presence of mountains which induce orographic rainfall. Thus, the latitude sometimes does not give exact type of climate. When relief interrupts the area, it results to modified climate such as modified equatorial climate, modified tropical climate and mountainous climate.

Water bodies

These are very good guide to climate types. The presence of many rivers indicates high rainfall, hence suggests equatorial climate, while the presence of salty lakes, bore holes, water holes, springs and wells imply dry conditions or semi-arid climate. Seasonal lakes and swamps suggest low rainfall and the area is marked by wet and dry seasons which denotes a tropical climate.

Vegetation

This is a good guide to map interpretation. The presence of forests and bamboo trees indicate high rainfall, which denotes equatorial climate in the area. Moreover, woodlands or grasslands reflect medium rainfall, while scrubs, thickets, thorny bushes and scattered bushes imply low rainfall which represents a semi-arid climate.

Crops

Crops can indicate the type of the climate of an area. Some of the crops such as coffee, rubber and tea are grown in areas which receive high rainfall, hence indicate presence of equatorial or mountainous climate. Other crops such as sisal, millet and cassava tolerate dry conditions and survive under moderate rainfall, hence indicate presence of tropical climate.

Relief

This is the surface form of the ground which shows size, shape, and slopes of the highland and lowlands. It is the changing nature of the land as observed from the sea level with its characterising landforms. An area can be described as highland relief if its average elevation is higher than one thousand metres above mean sea level.

Transport and communication

Though all types of transport are shown in topographical maps, the most common is land transport which includes railway lines, pipelines, and roads. Roads are shown in different forms like tarmac roads, also called all-weather roads, which are represented by a thick red line. Loose surface roads are indicated by thick broken line, dry weather roads by a continuous white line and footpaths.

Some topographical maps show well developed and distributed transport and communication routes than others. This shows that there is unequal development of transport and communication systems. Some of the factors that determine unequal development and distribution of transport and communication includes drainage, relief, human activities and climate. Apart from land transport, topographical maps also show air transport which is indicated by airfield runway and water transport indicated by large water bodies like lakes, seas and oceans.

Land use and functions

Different land uses both in urban and rural areas are well shown in the topographical maps. Urban land use is indicated by commercial land use, industrial land use, residential land use and open space land use. Rural land is used for different economic, political and social activities including commercial cultivation. The common land uses in rural areas are intensive cultivation land use, forestry land use, grazing land use and village settlement land use.

Relief representation and interpretation

The relief of an area is the surface form of the ground which shows size, shape, and slope of the highlands and lowlands. It can also be defined as the changing nature of the land or variation in the shape and form of the earth's surface as observed from the sea level. Highland relief is normally characterised by highland landforms such as mountains, escarpments, ridges, plateaus, valleys and spurs as well as, hills and ridges. Lowland relief shows average elevation below 1 000 m above the mean sea level. It is characterised by lowland features such as deltas, plains, estuaries and cliffs.

Representing relief on a map

There are two methods of showing relief, which are quantitative and qualitative methods. A quantitative method shows elevation of points, normally by using contour, spot height, trigonometrical and benchmarks. Qualitative method does not show numbers but uses hachuring, hill shading, block diagram (physiographic diagram), layer coloring, form lines and naming methods.

Hachuring method

This refers to the non-numerical traditional way of showing the nature of the terrain, by means of straight-short lines drawn in the direction of steep slopes (Figure 5.23). Their thickness and density increase with the increase in the degree of land steepness. Despite the fact that they are non-numerical, hachures can successfully communicate a quite specific shape of the terrain. They are suitable for mountainous regions for depicting landforms such as craters. They also give general ideas on the nature of the slope.

Hachures have the following limitations; Firstly, they cannot show the extent of height and steepness of the landform they represent. Secondly, different relief features such as mountains, hills, and direction of the water courses are difficult to be interpreted with the use of hachures. Thirdly, hachures are likely to obscure other features and their use consumes more time.

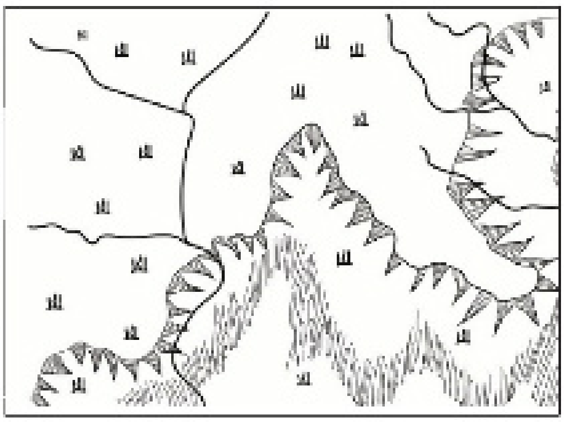


Figure 5.23: *Hachuring method*

Contour method

Contour lines on a map join points representing equal elevation above mean sea level. Usually, contours show various features or landforms like hills, plateaus, mountains and valleys, basins and plains. Contours also show gentle slopes when the contour lines are drawn far apart from one another and steep-slope when they are drawn closely. Contour lines are drawn at definite intervals, for instance 20 m or 50 feet, and do not cross one another. Contour lines form a 'V' pointing upwards to denote a valley and 'V' pointing downwards to denote a spur. The merits of contour is to give the exact height for a particular area since the contours are numbered (Figure 5.24). They are also used to give clue of physical features depending on the contour layout and they can be integrated with other methods like spot height and trigonometrical station.

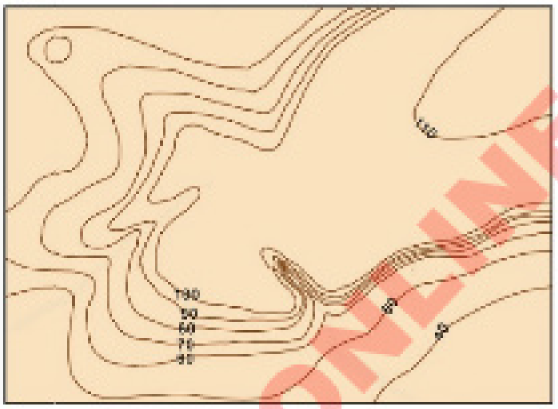


Figure 5.24: *Contour lines*

Form lines: are usually unnumbered lines drawn on a map joining points of nearly the same height. They are like contours but they use unnumbered lines.

Hypsometric colouring method

Hypsometric colouring, also known as layer tinting or colouring, is a method used on maps to re-enforce the impression of relief and to make the land forms more easily understood by map users. It is not a complete method in itself because it relies upon the presence of either contours or form lines to provide the basis for colouring. By convention, the lower elevations are coloured in various shades of green, intermediate areas in yellow, higher altitude zones in brown or red, then purple and white. The lightest colours are used where most details are in the lowland areas and the brightest colours where details are sparsely high.

With layer colouring, it is simple to identify the nature of the relief, whether lowlands or highlands, just by observing the change in colour rather than striving to find the values of height as with other methods like contour lines. The method is mostly used on small scale maps and atlas maps.

Different tones used in indicating the change in elevation make the map more attractive. For instance, green colour is used to indicate lowland and white or red colour is used for highland. A stereoscopic is produced in which the warmer colors such as brown and red appear nearer the map reader while the cooler colors like green and blue at lower elevations, appear further away. Although good in appearance, this may bring about confusion to some people since colors have multiple implications in people's minds. For example, green colour may suggest vegetation or fertility. However, not all lowlands coloured green are fertile. Additionally, layer tint maps are very expensive to produce. Lastly, the method cannot show a clear boundary between highland and lowland areas, though it uses different colours to indicate them.

Hill Shading

Hill shading is a method of showing relief in which parts of the map are darkened by a tint or stipple of chosen colour as if they are in a shadow cast by an imaged object. It can give a fine, modelled impression of relief that strikes out eyes at once. The slopes can be shown easily as the shadow tone is darker on steep slopes and lighter on gentle slopes. The method tends to make the slopes in shadow to look steeper than they really are. The impression of relief is sometimes much greater than the sense of it, for example, the location of "ups" and "downs" (Figure 5.25).

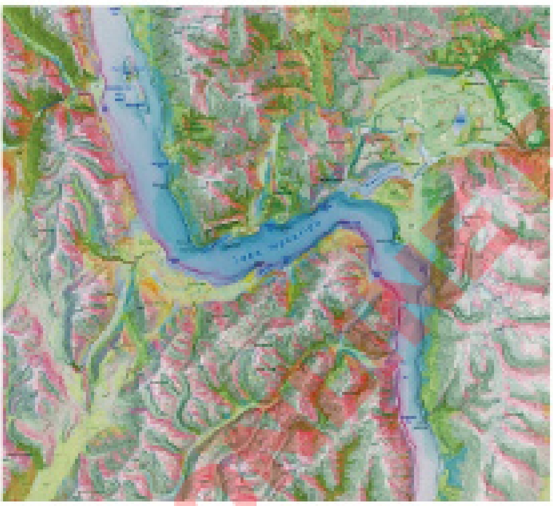


Figure 5.24: *Hill shading method*

Trigonometric point method

Trigonometric point is the method of representing relief whereby a point is accurately surveyed and shown on the map, with their actual heights in metres or feet above mean sea level. The method is usually represented on the map by a triangle and a dot with exact height. For example, △8848 m. After surveying, the surveyors erect concrete pillars on the summits of the hills, which act as corners of the main triangles of the survey. In this method it is easy to recognize the height of a given point on the map. Sometimes, a trigonometric point is called a trigonometric station. The method is used with contour lines for mathematical interpretation of the map, such as determination of the slope and drawing of relief section.

Spot height method

Spot height is the method of representing relief whereby a point is accurately surveyed and its actual height above mean sea level is shown in metres or feet on a map. The method is normally represented by dot and exact height such as • 5895 m, or represented by a small circle with dot and height number, for example ⊙ 5895 m. In this method, there is no physical evidence of spot heights in the field, but they appear frequently on maps, along roads and between contours near sea-level to help in interpretation of relief.

With spot height it is easy to recognise the height of a given point on the map, unlike with the use of contour lines and psychometric tinting method. Spot height method can be used with contour lines to prepare the cross section. It is also very useful in some mathematical interpretation of the mapped areas such as determination of slope. It may provide important elements or clues on the nature of the relief, and become the basis of the relief description. The use of spot height as the method of showing relief features does not obscure other details. However, with this method, it is very difficult to clearly understand the nature of relief features like mountains, valleys and steep slopes in a particular mapped area.

Benchmarks methods

A benchmark (BM) is a mark on a permanent object, which indicates an elevation of a point. Benchmark serves as a reference point from which measurement of topographical surveys may be made. They can be found in the brick or stone of a building or a wall. It is shown by a symbol BM followed by a numerical height, for example BM 1554.

Naming method

Naming method is the method of showing relief whereby specific landforms (relief features) are identified on a topographical map by using their names.

Relief section

A relief section, also known as cross section, shows the shape of a feature (such as a mountain) viewed from the side, as if cut through with a knife. It is a lateral view of the relief and a graphical representation of the terrain along the line. There are three (3) forms of cross section which are:

(a) Simple relief section: this shows only relief between two points.

(b) Annotated section: it shows relief with other information that crosses between two points including vegetation, road and river.

(c) Sketch transcend section: this shows only the highest and the lowest points. It portrays a rough picture of the general appearance of the landscapes.

The construction of a relief section involves the following procedures:

(i) Identify and mark positions, features and heights;

(ii) Draw a light-pencil line joining the two points;

(iii) Transfer the line drawn on the map between two points to the graph paper;

(iv) Place or lay the straight edge of the paper along the drawn line, mark the point where contour crosses the line and indicate the responsive elevation. If the same contour crosses twice or more, mark it with the same elevation;

(v) Choose a vertical scale which will show the variations in relief but without exaggerating them too much. For suitable vertical scale, use guidelines by observing the type of scale given;

(vi) Determine the vertical interval as

$$VI = \frac{H_1 - H_2}{n+1}$$

where by H_1 is the upper labelled contour and H_2 is lower labelled contour, and n is number of non labelled contours between H_1 and H_2;

(vii) Draw the vertical lines and plot the points; and

(viii) Link the dots using a continuous smooth line to indicate the relief.

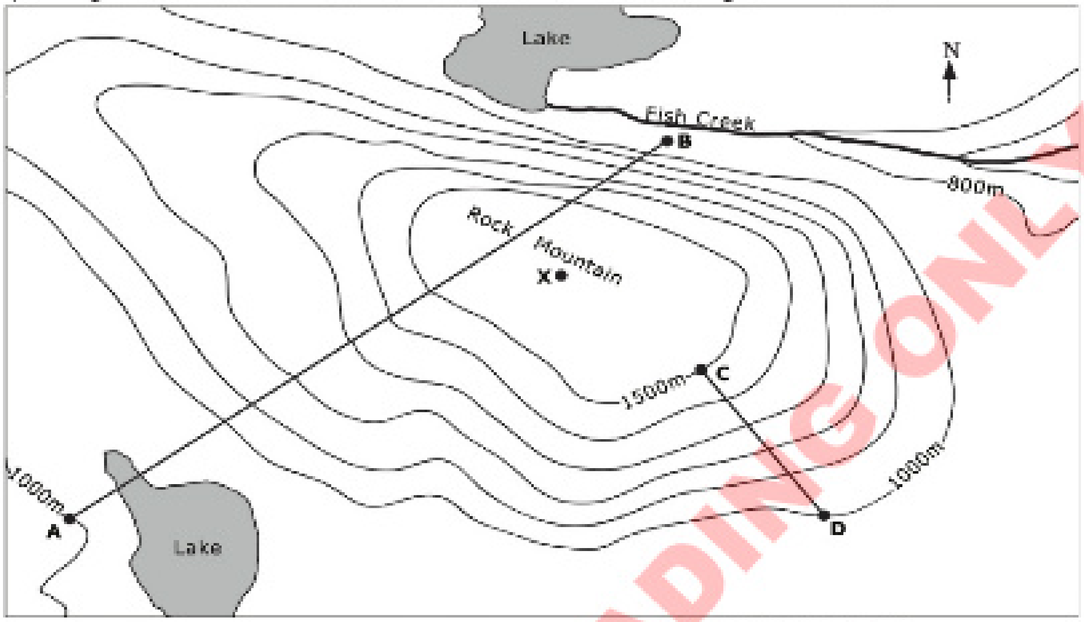
Example

Study the contour map and answer the following questions.

(a) Prepare simple cross profile between point A and B.

(b) Draw an annotated relief section between point A and B.

(c) Prepare sketch/transcend relief section between point A and B.



Scale 1:50 000

Solution

Formula for vertical interval (V.I)

$$V.I = \frac{H_1 - H_2}{n+1} = \frac{D}{n+1}$$

Where by

D = Difference between two contours, example $\overline{AB}$

n = Number of contour lines which are unnumbered

From the map

H_1 = 1500m at c

H_2 = 1000m at D

n = 4

Then $$V.I = \frac{(1500-1000)\text{m}}{4+1}$$

$$= \frac{500\,\text{m}}{5}$$

$$= 100\ \text{m}$$

V.I = 100m

Therefore, the interval between two consecutive contour lines is 100 m.

An annotated cross profile between point A and B

V.S = 1 cm : 100 m

1 cm =100 × 100 cm

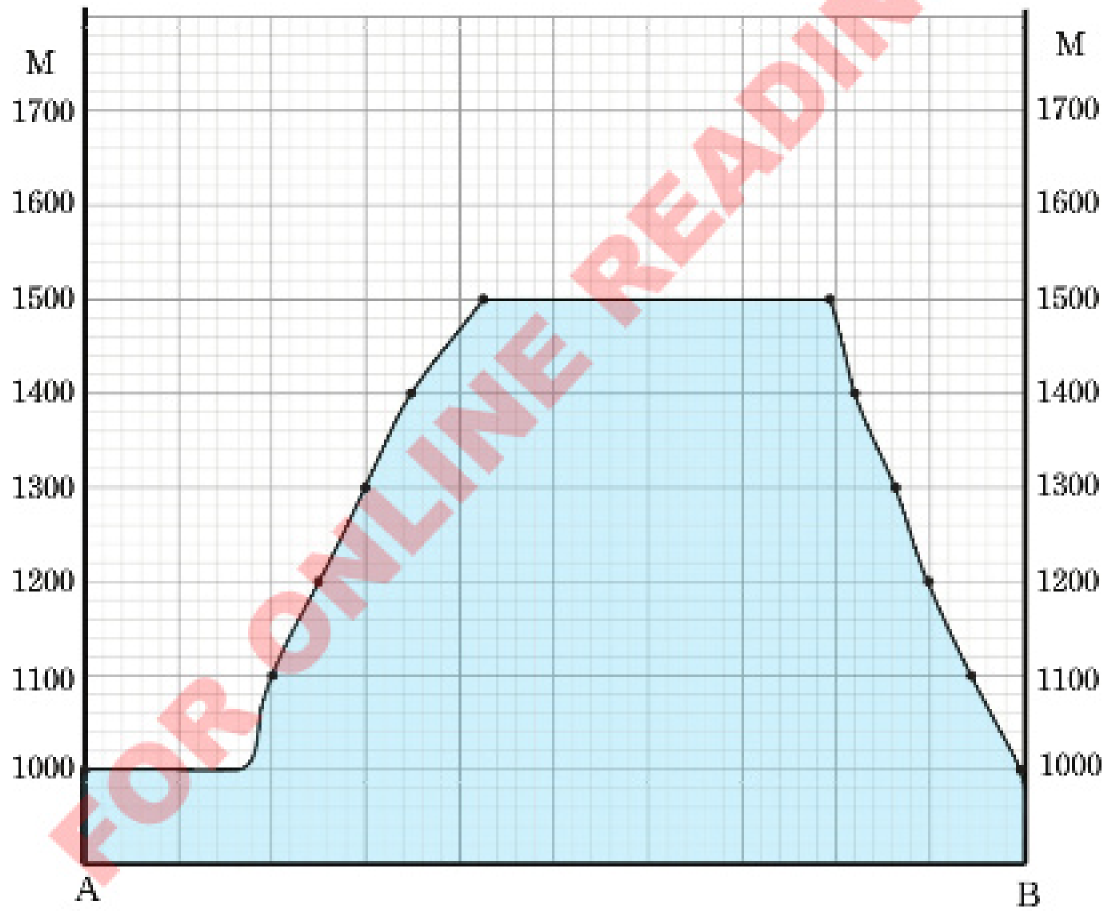
$$\frac{1cm}{1cm} = \frac{10000cm}{1cm}$$

V.S =1:10 000

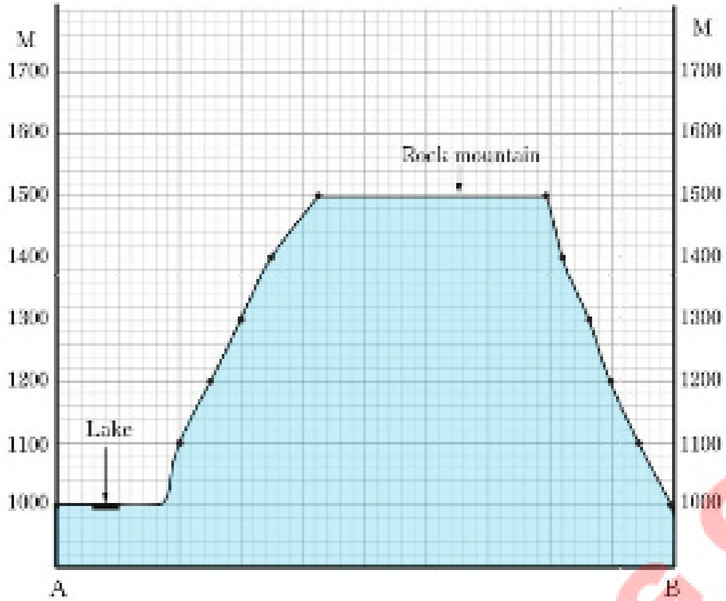
Therefore: V.S: 1 cm represents 100 m

H.S =1:50 000 (1cm represents 50 000 cm)

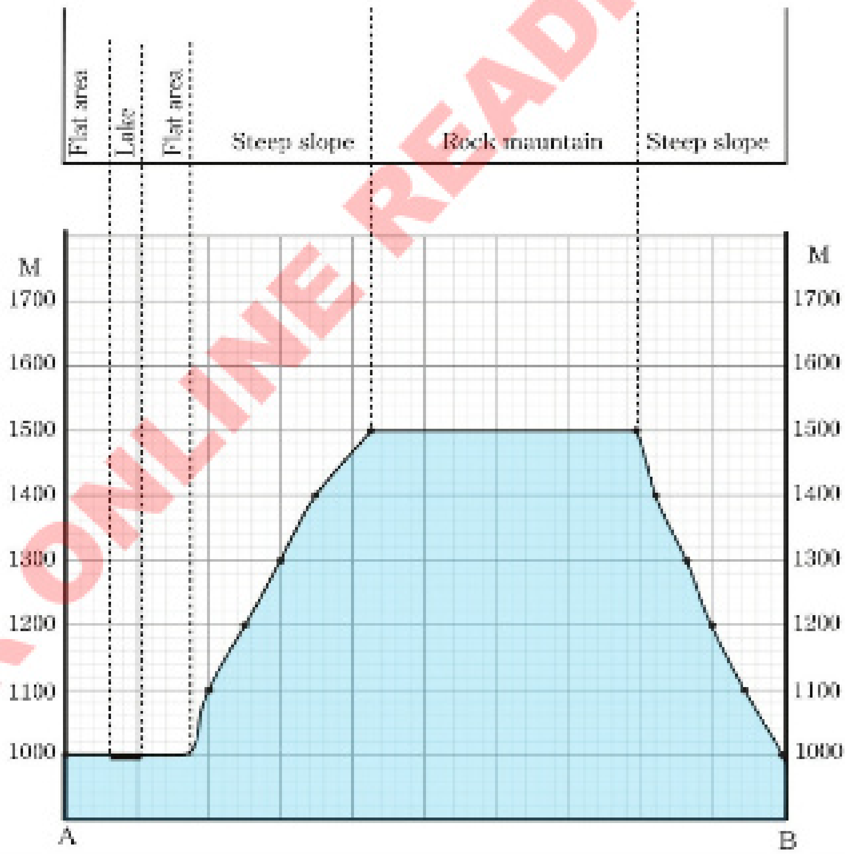
(a) Simple cross profile between point A and B



(b) An annotated cross profile between point A and B



(c) Transcend/sketch relief section between point A and B



VS = 1 cm represent 100 m

HS = 1cm represent 0.5 km

All procedures followed when drawing annotated cross-section are the same for drawing sketch or transcend cross section, only that in sketch cross-section, labelling of relief features and other information found between the points of cross section area are shown on the table above the cross-section graph.

Vertical exaggeration

Vertical exaggeration is a scale that is used in raised-relief maps, plans and technical drawing in order to emphasize vertical features, which might be too small to identify relative to horizontal scale. Alternatively, it is defined as the number of times the horizontal scale is greater than the vertical scale. For example, from the above relief section, vertical exaggeration can be calculated as follows:

$$\text{Vertical Exaggeration} = \frac{\text{Vertical scale}}{\text{Horizontal scale}}$$

$$\text{or Vertical Exaggeration} = \frac{\text{Demominator of horizontal scale}}{\text{Demominator of vertical scale}}$$

For example, if

VS = 1:10 000

HS = 1:50 000

$$VE = \frac{1:10\,000}{1:50\,000} \text{ or}$$

$$VE = \frac{50\,000}{10\,000} = 5$$

VE = 5 times horizontal scale

Note: V.E Has no unit.

Gradient

Gradient refers to the steepness or gentleness of the ground in relation to the horizontal plane. Gradient is expressed as the ratio or fraction of vertical rise to the horizontal equivalent, in which the numerator represents vertical rise and the denominator represents the horizontal equivalent. The extent of steepness or gentleness depends on the size of the denominator in the sense that when the denominator is too small, the gradient is steeper and when the denominator is too large, the gradient is gentle.

Procedures for calculating gradient.

(i) Identify and mark two points by using grid reference or any other means of locating position;

(ii) Join the two points by a straight line and measure the map distance apart;

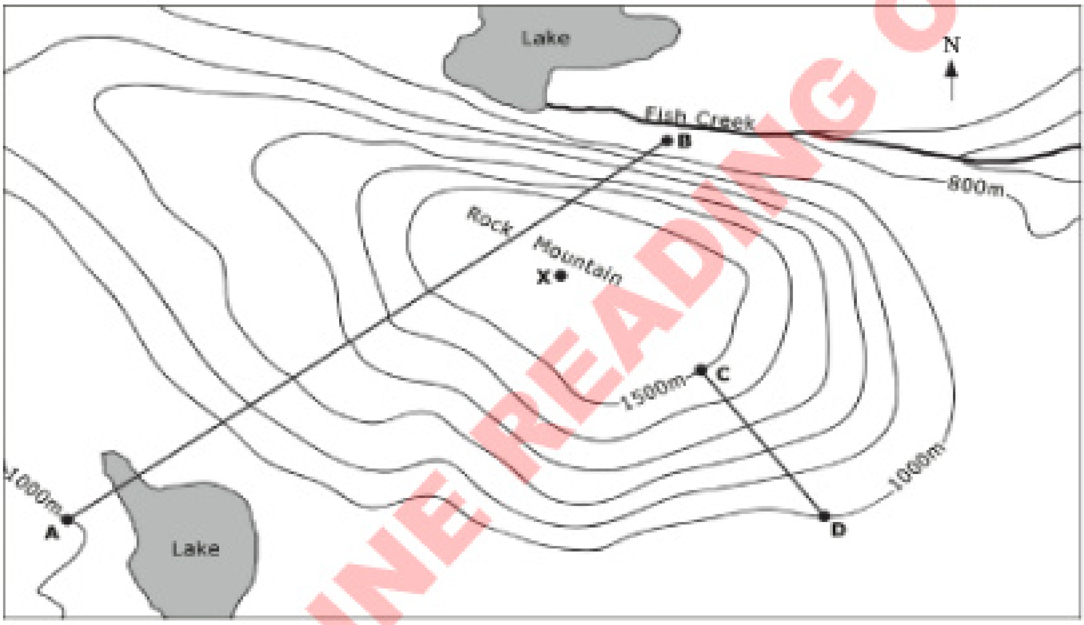
(iii) Identify the highest and the lowest points and extract their elevation. If they are in feet, change them into metres;

(iv) Convert the measured map distance into ground distance to get horizontal distance in metres;

(v) Divide the difference between the highest and the lowest elevation by the corresponding horizontal distance. Leave your answer in the simplest form of fraction such that gradient = $\frac{a}{b}$ where "a" represents vertical increase and "b" represents horizontal equivalent.

Example

Study the map provided below and then find the gradient from point C to D.



Scale 1:50 000

Solution:

$$\text{Gradient} = \frac{\text{Highest point} - \text{Lowest point}}{\text{Horizontal equivalent}}$$

Data given

Highest point = 1 500 m

Lowest point = 1000 m

Map distance = 7 cm

Map scale = 1:50 000

Changing map scale from RF to statement scale as follows:

$$1:50\ 000$$

$$1 \text{ cm} : 50\ 000 \text{ cm}$$

$$\text{Since } 1 \text{ km} = 100\ 000 \text{ cm}$$

$$? = 50\ 000 \text{ cm}$$

$$\text{Therefore, } 1 \text{ cm} : \frac{50\ 000 \text{ cm} \times 1 \text{ km}}{100\ 000 \text{ cm}}$$

$$1 \text{ cm} : 0.5 \text{ km}$$

Convert horizontal map distance into horizontal ground distance using the statement scale as demonstrated hereunder:

$$1 \text{ cm} = 0.5 \text{ km}$$

$$7 \text{ cm} = ?$$

$$= \frac{7 \text{ cm} \times 0.5 \text{ km}}{1 \text{ cm}}$$

$$= 3.5 \text{ km}$$

Since,

$$1 \text{ km} = 1\ 000 \text{ m}$$

$$3.5 \text{ km} = ?$$

$$= \frac{3.5 \text{ km} \times 1000 \text{ m}}{1 \text{ km}}$$

$$= 3\ 500 \text{ m}$$

Finally, the gradient is calculated as follows:

$$\text{Gradient} = \frac{1\ 500 \text{ m} - 1\ 000 \text{ m}}{3\ 500 \text{ m}}$$

$$= \frac{500 \text{ m}}{3\ 500 \text{ m}}$$

$$= \frac{5}{35} = \frac{1}{7} = 1:7$$

Gradient = 1 in 7 or 1:7

This implies that, for every horizontal distance of 7 m, the land rises by 1 m.

Drainage interpretation

Drainage can be defined as the runing water in an area by natural or artificial streams, rivers, and infiltration as it is commanded by the nature of geology and relief of the particular area. Variation in the nature of relief and rocks determine the types of drainage patterns. Drainage pattern is the layout or plan made by rivers and their tributaries on the landscape. Streams and rivers are by far the most important landscapes forming elements. In map reading and interpretation, the drainage pattern forms a convenient unit of study which can be outlined and readily defined on a map. Drainage can be classified according to the pattern formed in relation to surface relief or the slope of the land, differences in rock hardness and rock structure. Various drainage patterns are related to the surface rock structure. Such patterns are explained below.

Dendritic pattern

It is shaped like a trunk and branches of a tree, usually with tributaries converging on the main stream from many directions and merging at acute angles as shown in Figure 5.26. Such patterns occur in rocks which are homogeneous (similar). They are commonly formed on massive crystalline rocks like granite or horizontal to gently dipping sedimentary strata. They are not related to rock structure or differences in rock hardness.

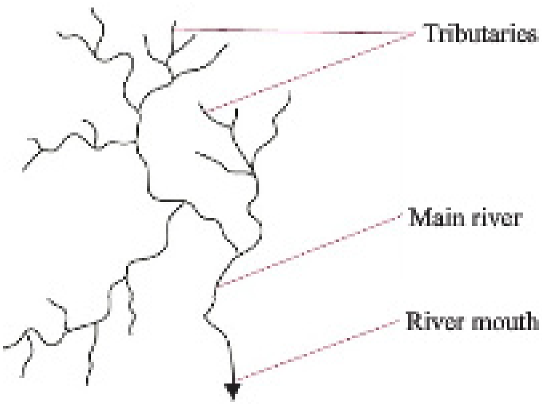


Figure 5.26: *Dendritic drainage pattern*

Trellis drainage pattern

It is a linear pattern in the shape of a lattice with the chief tributaries joining the main stream approximately at right angles as shown in Figure 5.27. Usually, minor tributaries join the chief tributaries at right angles and flow more or less parallel to the main stream. The pattern is strongly related to structure or differences in rock hardness (heterogeneous rocks) and is commonly found in scarp land areas and regions of folded rocks. Normally, it is found in folded sedimentary rocks and metamorphic rocks. The chief tributaries are usually aligned along down-fold or parallel zones of weak rocks separated by resistant uplands.

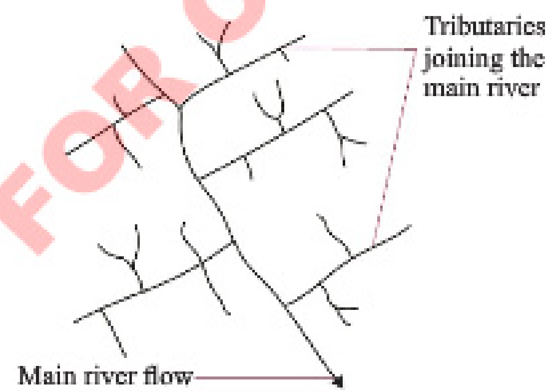


Figure 5.27: *Trellis drainage pattern*

Radial drainage pattern

This is an arrangement of streams flowing outwards down the flanks of a dome or cone-shaped upland such as a large volcano (Figure 5.28). It is common in volcanic regions and is controlled by the gradient of the land.

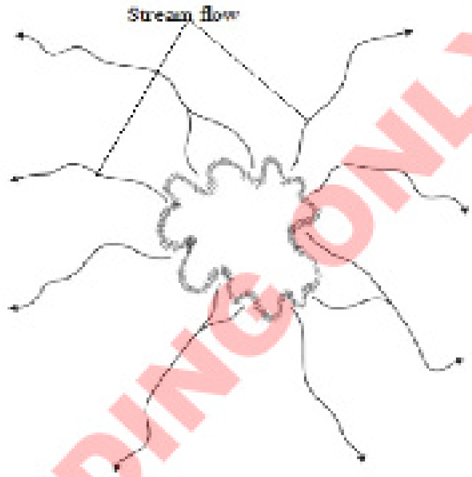


Figure 5.28: *Radial drainage pattern*

Annular drainage pattern

Is the pattern with streams often joining at sharp angles but arranged in a series of curves about a dissected dome, basin or crater area. On a dissected dome with alternating bands of hard and soft rocks the pattern may appear as several concentric curves (Figure 5.29). It is common in volcanic regions.

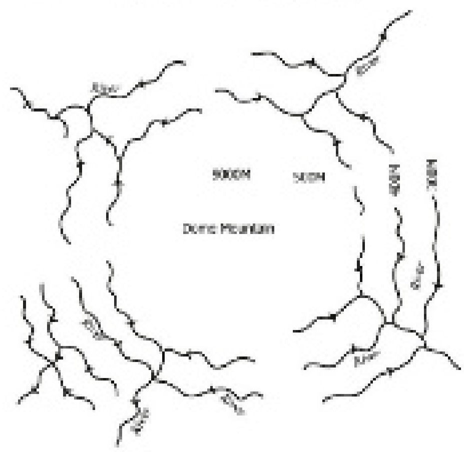


Figure 5.29: *Annular drainage pattern*

Rectangular drainage pattern

This pattern is similar in plan to the trellis, with tributaries joining each other at approximately right angles. Rectangular pattern also tends to have individual streams taking sharp angular bends along their course (Figure 5.30). The pattern is the result of structural control, with streams following joints or fault lines in the rock. It is common in volcanic regions, and granitic rocks.

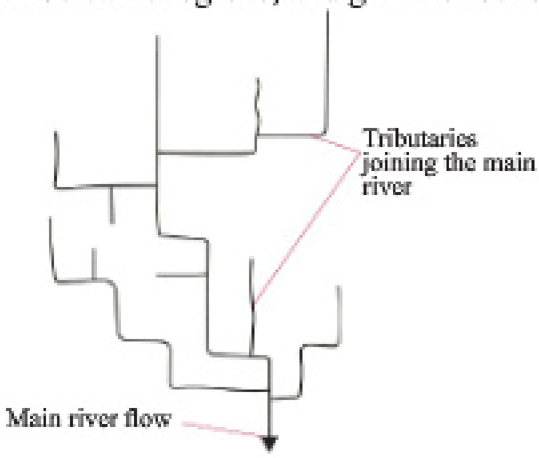


Figure 5.30: *Rectangular drainage pattern*

Braided drainage pattern

This is common in broad flood plains with low gradients, often due to back tilting (Figure 5.31). A good example is at Mazinde area, Lushoto in Tanga region.

Figure 5.31: *Braided drainage pattern*

Regulated drainage pattern

Regulated pattern is common in flat sediments of recent age in coastal zones, associated with tidal rivers, numerous cracks and coastal swamps (Figure 5.32). It is very common along the coasts of West and East Africa.

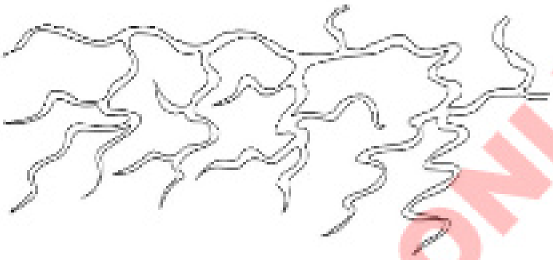


Figure 5.32: *Regulated drainage pattern*

Anastomotic drainage pattern

This pattern is very common in areas with flood plains in coastal zones or reduced gradients inland due to back tilting (Figure 5.33). It is very common for numerous double channels, ox-bow lakes, cut-offs, and abandoned meanders. Rivers or streams will generally follow the line of least resistance such as along a band of softer rock, a fault line or the crushed fault breccia between two faults.

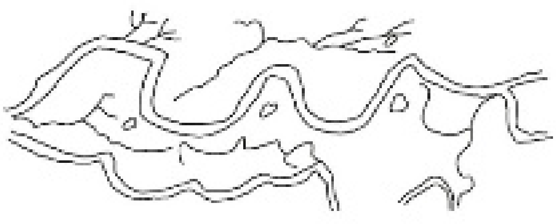


Figure 5.33: *Anastomotic pattern*

Centripetal drainage pattern

This drainage is opposite to the radial drainage pattern because it is characterised by the streams which converge at a point which is generally a depression or basin. This drainage is formed when a series of streams converge in a central low basin or crater lake (Figure 5.34). A good example of this drainage pattern can be found in Kondoa District, Tanzania.

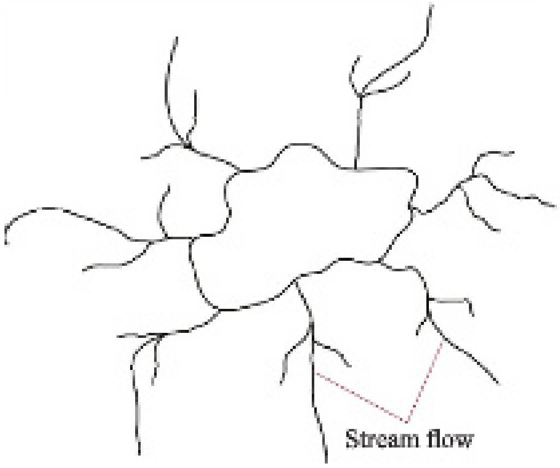


Figure 5.34: *Centripetal drainage pattern*

Parallel drainage pattern

Parallel drainage pattern comprises a number of rivers which are parallel to each other and follow the original slope (Figure 5.35). This pattern is more frequently developed on uniformly sloping and dipping rock beds such as Cuesta or newly emerged coastal plains.

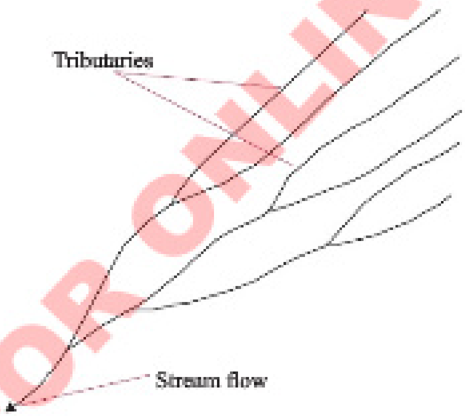


Figure 5.35: *Parallel drainage pattern*

Vegetation interpretation

A topographical map shows both natural vegetations such as forests, Savannah, thicket, shrubs, thorny, swamp vegetation, bamboo, mangrove swampy, scattered bushes and others as well as artificial vegetation which may be indicated by plantations. Sometimes vegetation is also indicated by pictorial symbols which show increasing density by placing the symbols closer together or giving the area a green tint. Dark green colour may be used to this effect.

In interpretation of vegetation, a geographer should consider the nature or type of vegetation and the way it is distributed. To determine what vegetation appears in which part of the mapped area, consider the cardinal points or names to indicate the nature of distribution. For example, the Eastern side of the mapped area is covered by scattered trees and scrubs while in the North-western part is dominated by thick forest.

In describing vegetation distribution, the geographer should also consider factors which influence the presence of vegetation in the particular area. Normally, the number of factors including soil quality, relief, water bodies, human activities and climatic conditions influences vegetation distribution. A detailed description of vegetation, soil and climatic relationships is presented in Table 5.3.

Table 5.3: *Vegetation, soil and climatic relationships*

Vegetation type	General description	Climatic relationship	Soil relationship
Forest	Closely spaced tall and medium trees, mixed or in simple stands with or without bushy undergrowth	Rain most of the year, rainy slopes of mountains, tropical and equatorial coastal lowlands	Thick and fertile soil
Savanna	Open with fewer trees than closed savanna Scattered trees, tall grasses and thorns	A pronounced dry season, but annual total rainfall permits tree growth	Widely varying soil from black cotton to sandy or volcanic
Dense, medium or sparse bush	The drier the climate, the frequent the bush, thickets frequent (tangles of several bushes) tufts of grass or bare sandy patches between bushes and thickets	Long dry season generally prevents trees growth except for occasional euphorbias or baobab	Similar to Savanna but usually thinner and drier sandy types
Scrub	Low profile thorn trees often rugged and twisted with scattered clumps of thorny bush and drought resistant grass	Very long dry season, rain unreliable	Usually sandy thin soils
Heath	Tufts of grass growing in close formation, heath and sometimes grant groundsel and lobelia	Moderate to heavy reliable rainfall at high altitudes (above 3500 m) with cool temperature	Infertile acidic soil
Mangrove swamp	Low bush-like trees with long roots often exposed at low water	Hot, wet lowland areas along coasts or lake shores and rivers; high humidity	Silt or mud soil, salt or fresh water. Water logged soil along river banks and lakes
	All strong grass with stiff spikes which often key sense growth	High temperature, rainfall not reliable water supplies by lake	

Settlement interpretation

Settlements refer to a organised permanent or temporary inhabitations of humans on a small or large area of land including slums or the requisite infrastructural facilities. Settlements range in size from small to large. Settlement is another basic aspect of topographical map interpretation.

Types of settlement

There are two types of settlements, namely urban and rural settlement. Urban settlement is an area where approximately 80% of the population are engaged in non-agricultural activities. This type of settlement is commonly found in district head quarters, regional administrative centres and along transportation routes.

Urban settlement is simply identified through highly built areas, as well as dense linear and nucleated settlement patterns.

Rural settlement is an area where approximately 80% of the population are engaged in agricultural activities. Rural settlements are commonly found in countryside areas and villages. In the interpretation of settlements, geographers have to consider how and where the dots representing people, houses or buildings and the town are located. Rural settlements are revealed in the map by sparsely huts, light linear and nucleated settlement patterns.

Settlement should be studied systematically by looking on aspects such as site, situation, form, pattern and function.

Site: is the nature of land on which the settlement is built or where a town or village is built. The site may be chosen for different reasons such as relief and gradient. For example, flat areas may be preferred for easy building. Areas with availability of water bodies such as rivers, streams, and lakes; fertile soil; presence of transport and communication network, defensive sites such as mountainous areas can also be chosen. Sometimes, site choice can be influenced by government policies. The government can allocate the use of land depending on its potentiality.

Situation: is the settlement's position in relation to other conditions such as physical features, important economic zones and communication. For example, the village may be situated on a river bank above flood level. The site will be convenient because of the availability of a nearby water body. This means that, settlement is well established in an area when site and situation conditions are not conflicting.

Form: this refers to the general shape of the settlement. Usually, a topographical map may indicate the features which have influenced the form of the settlement. For example, the basic urban forms are linear which may result from existing linear features such as valleys, the alignment of a route way or river or an elongated relief feature such as a ridge or escarpment base. Other forms of settlement include concentric circular form, where growth has been generally outward from a central core or nucleus. With rectangular form, the town develops in blocks. A good example is Hastings town in Sierra Leone.

Settlement pattern: describes how the settlement is distributed. In this aspect, we can examine the size of settlements in relation to the environment and we can study the pattern and shape of settlements. Normally, settlement morphology (pattern) is determined or controlled by its main function, particularly human activities. There are three types of settlement pattens, namely linear, nucleated and dispersed settlement patterns as shown in Figure 5.36.

Linear settlement pattern: occurs in the area where the marketing of cash crops depends upon ease of transport, or along communication and transport routes such as roads and railways. Some areas follow the pattern of river valleys.

Nucleated settlement patterns: represents settlement areas characterised by clustered or closely grouped buildings normally for economic and social purposes. It is common in town centres, village centres, coastal areas, borders of two countries and around road junctions or river crossing. It is common in places where there is settlement around nuclei areas such as market or mining centers.

Dispersed settlement pattern: occurs in the area with sparsely or scattered people, with few houses far apart. Such pattern can be found in pastoral societies.

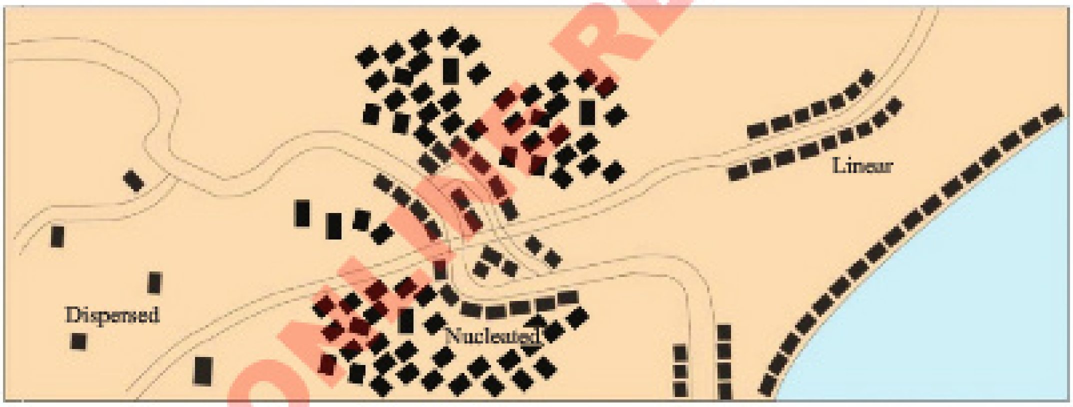


Figure 5.36: *Three types of settlement patterns*

NOTE: Settlement morphology or pattern changes with time due to social, political and economic development. An area with scattered settlement may over time be dominated by nucleated settlement.

Function: is another technique of interpreting settlement. Land use pattern within a form of larger settlements may reveal well-defined functional zones, in which there are varieties of specified activities. Such zones include the Central Business District (CBD), which is a rectangular grid pattern of high class and specified shops, offices and banks located near the centre of the settlement. The zone is neither residential nor industrial. Generally, the function of a settlement reflects its economic and social development activities. More examples of functional zones which can be indicated on a map are as follows:

The administrative function is indicated by government offices such as Headquarters (HQ), District Council (DC) and Regional Council (RC).

Recreational function is usually indicated by different man-made features such as car parks, gardens, football grounds, boating lakes, race courses, golf courses and zoos.

Cultural function is normally indicated by cinemas, museums and libraries.

Educational function is depicted by schools, colleges, universities, research centres, library buildings and education offices.

Industrial function is usually spacious in layout and well away from the main centre and residential areas and very often downwind to avoid pollution.

Cultivation function is normally located in margins of most large towns and cities. Horticulture is practiced to serve the industrial and business purposes.

Marketing/trade function is indicated by buying posts, town, market, and nuclear settlement pattern.

Residential function is classified on the basis of low, medium and high density. The infrastructure serving the settlement like electricity, water pipes, dams, railway lines and roads are good indicators of a residential zone.

The number of institutions such as government offices, police stations, army barracks, churches, colleges and the like, are significant to support living, hence considered important indicators for this zone.

Functional zones may be more easily defined in large urban centres than in smaller settlements. In smaller settlements, one looks for emerging or embryo functional zones and tries to depict what future development they are likely to produce.

Rocks interpretation

Rocks vary in hardness with metamorphic being the hardest while the sedimentary are the softest. Table 5.4 shows some hints that help to deduce types of rocks on a given topographical map.

Table 5.4: *Identification of types of rocks on a topographical map*

Types of rocks	Possible evidences		
	Land forms	Water bodies	Vegetation & Crops
Igneous rocks	• Mountain • Hill • Crater • Caldera	• Radial drainage pattern • Dendritic drainage pattern • Annular drainage pattern	• Thick dense forest • Tea plantation • Coffee plantation • Pyrethrum
Sedimentary rocks	• Coral reef • Coast land • Cave • Delta • Cliff • Depression	• Salt lake • Regulate pattern • Braided drainage pattern • Water holes • Bore holes	• Mangrove swamps • Tree swamps • Seasonal swamp • Sugarcane plantation • Rice plantation • Sea weed plantation
Metamorphic rocks	• Outcropped rock • Undulating plateau	• Trellis drainage pattern	• Scrubs

Interpretation of geomorphic processes

In topographical maps, it is possible to identify geomorphic activities reshaping the mapped area. A geographer can identify both endogenic (folding ,faulting and vulcanism) and exogenic (denudation and deposition) activities. This can be done with the help of the nature of relief depicted and its associated landforms. Table 5.5 shows some hints for identifying geomorphic processes affecting the landscape.

Table 5.5: *Geomorphic processes affecting the landscape*

SN	Process/activity	Common evidence
1	Vulcanism	Crater, hill, mountain
2	Faulting	Escarpment, mountains, valleys
3	Folding	Mountain, valleys and spurs
4	Erosion	Rivers, lakes, oceans, hills, valleys
5	Deposition	Lakes, rivers, swamps, oceans
6	Weathering	Rocks, out crops, mountains

Interpretation of human activities

Maps describe the way man feeds himself and earns his living. The following are some simple hints that can be used to describe economic activities.

Cultivation

Farming is among the basic and the widespread economic activities of man. The topographical maps show both small and large-scale farming. Small scale farming is represented by scattered settlements, scattered cultivation and inland water bodies while large scale farming is portrayed by estates or plantations.

The presence of ginneries for cotton; hullers for coffee; jiggery works for sugar; tea factories, Cotton Buying Post (CBP) and maize mills indicates farming. In addition, cultivation can be presented by the word scattered cultivation.

Pastoralism

Livestock keeping is not easily seen on maps. Grassland areas with scattered clusters of dwellings and perhaps water pans, water holes, dams and boreholes are the settings likely to represent pastoralism. In addition, look out for named veterinary installations, water-pump tanks, cattle and quarantine camps, trough races, cattle and creameries.

Manufacturing Industries

Ginning, hulling, tea and sisal processing are often done in the countryside, but East African industries are in or near the larger towns. Normally, urban settlement indicates industrial activities. Special symbols and signs can also be used to identify industries. Some words such as ginnery, factory or industry can be applied. Similarly, large scale plantation indicates the presence of processing industry.

Trade

It focuses on buying and selling goods and services. It is depicted by the presence of a communication network (roads, airways and railways), markets, shops, trading centres and settlements.

Mining and quarrying

Some places in the drier rift valley floor are exploited for salt or soda. Nevertheless, mineral symbols, salt works, mineral works and quarries are mostly preferable. They are also indicated by presence of brick or cement industries since they depend on limestone or sand as their raw materials.

Logging

Logging, also known as lumbering, refers to the activity of cutting down trees in order to use their related products like wood. Woods are used to produce timber (lumbering), charcoal and poles for electricity, furniture as well as different industrial materials. On a map, evidence such as saw mills and minor roads ending in forested areas depict logging. Some forest reserves are exploited for timber, but many are not meant to be exploited.

Fishing

Settlement along water bodies such as rivers, seas, oceans and dams indicate fishing activities. Similarly, this is indicated by the presence of fish traps, fishing market centres and net drying yards.

Tourism

The presence of National Parks or National Reserves antiquities, volcanic and coastal features, hotels, gymnasium, cultural features physical or scenery can be preferred to indicate tourism in the mapped area.

Social activities

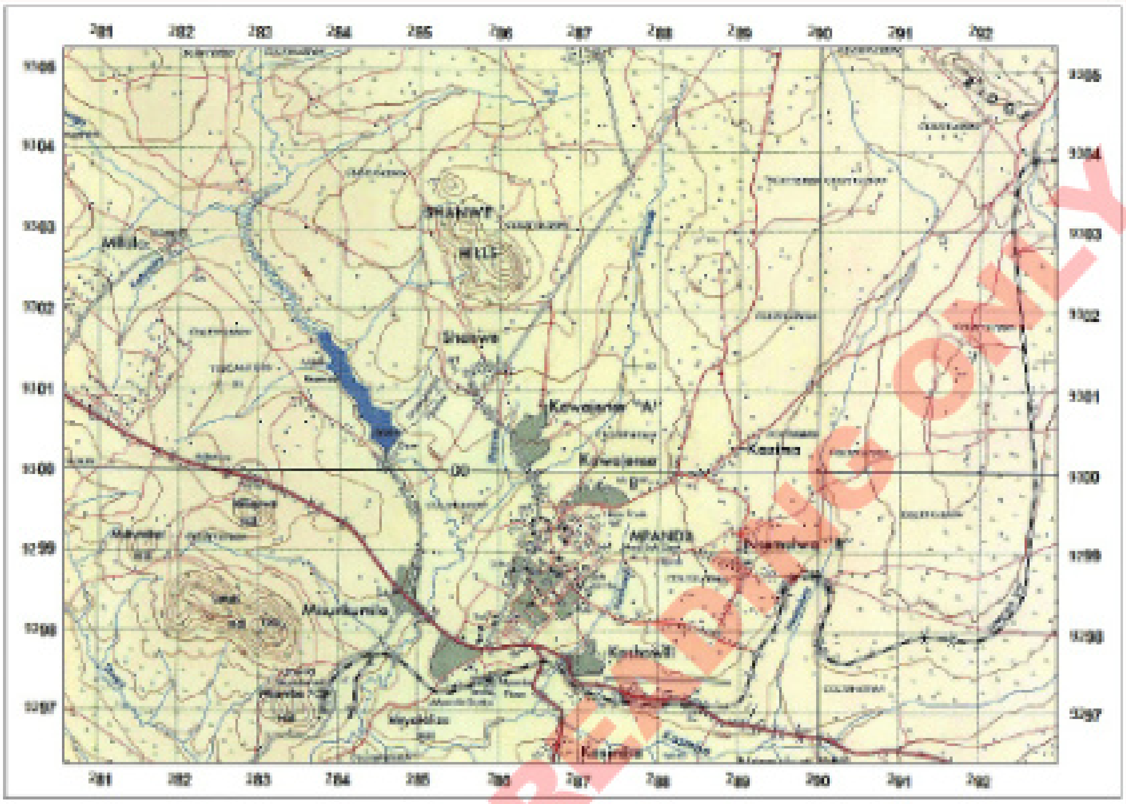
Social activities are services provided for the benefit of the community. They are activities which aim at solving social problems or needs and, therefore, generate social impact. Some social activities are like religious activities, health services, educational activities, transport and communication, administrative activities, security services, power supply services, banking services and recreational activities. These social activities can be presented on a map in different ways.

Religious activities can be indicated by worshipping centres such as churches, mosques, and temples. Health services are indicated by health facilities such as health centres, hospitals, dispensaries and clinics. Educational activities are depicted through schools, colleges and training centres. Administrative activities are indicated by Headquarters (HQ) offices and Local Government Headquarters (LGHQ). Security services are shown by Police posts and military camps. Recreational activities are denoted by play grounds such as tennis grounds stadium, cinema halls, race tracks, camp sites, and resorts. Water supply services are denoted by water tanks, taps, large water bodies, or underground pipelines. Power supply services are shown through power stations, power houses and electricity poles. Transport and communication are indicated by roads, railway lines, airports, aerodromes, ports, large water bodies, and telephone lines.

Revision exercise 5

1. Study carefully the map extract of Mpanda and answer the following questions.

MPANDA



Scale 1:50 000

(a) Re-draw the map provided using a scale of 1:100 000, then show the following features:

(i) Shanwe hill (ii) Railway line (iii) Dam (iv) ridge (vi) Airport

(b) Madam Halima was driving a car from Kasimba village grid reference 867964 to milestone area grid reference 823001.

   (i) Find the distance covered by Madam Halima in km if the map scale is changed to 1:25 000.

   (ii) Find the trend and alignment.

(c) (i) Draw an annotated cross profile between grid reference 810970 and 840010.

   (ii) Calculate its vertical exaggeration.

   (iii) Are the two points intervisible? Give reason(s).

(d) (i) Name the feature located 4.75 km (270°) from grid reference 890005.

   (ii) Determine the area of the feature in (d) (i).

   (iii) Enumerate ecological, social, and economic importance of the feature mentioned in d (i).

(e) Re-draw the part of the map bounded by the following grid references 840040, 860040, 840010, and 860010. Recommended scale is 1:25 000.

(f) Mr. Kipanda, a regional surveyor, recorded 256° and 78° as his forward and backward bearing, respectively. Correct discrepancies.

(g) Describe the type of the map title.

(h) (i) Why is contour used as the most common method of showing a relief?

   (ii) Apart from contour lines, what other method(s) have been used to show relief of the mapped area?

(c) Describe social economic activities of the mapped area.

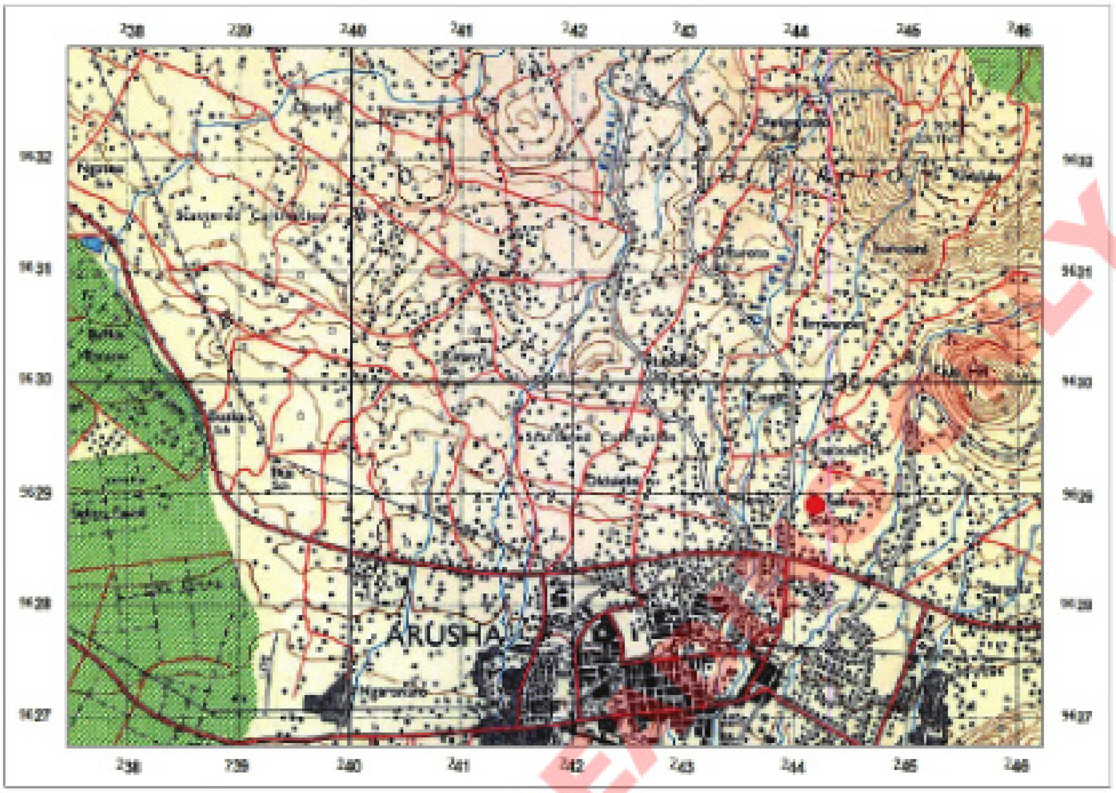
(d) Identify types of rocks that are predominant in the area.

(e) Comment on the population distribution of the area.

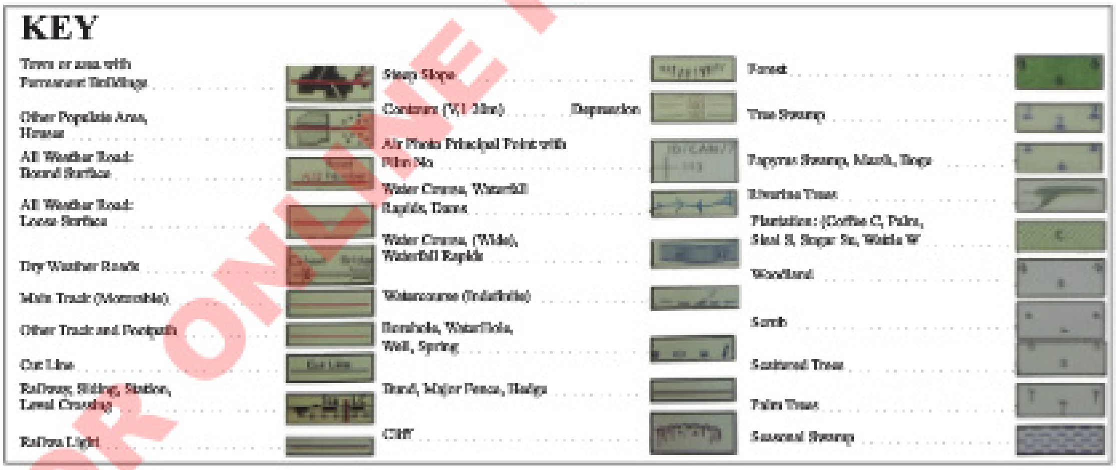
(f) With clear evidences from the map, suggest the type of climate and drainage patterns.

2. Study carefully the map extract of Arusha Sheet 55/3 and answer the questions that follow.

ARUSHA



Scale 1:50 000



(a) Describe geomorphic activities shaping the landscape of the mapped area.

(b) Comment on the possible types of soil on the mapped area.

(c) Describe the relief of the mapped area.

(d) Provide three reasons for the absence of swamps in the area.

(e) With evidence, provide three criteria which can be used to deduce human activities in the area.

(f) Outline limitation of contour lines in depicting relief features.

(g) Name two drainage patterns shown in the map and for each, provide at least one factor that determines its formation.

(h) Describe the nature and distribution of vegetation in the area.

(i) Comment on the factors that have influenced the nature of land use in the mapped area.

(j) Briefly explain the strength of marginal information in interpreting the given map.

(k) Explain the factors which determine the nature of settlement patterns in the mapped area.

Conduct a project in Geography:

Select an issue related to Practical geography, then design and conduct a project.

Glossary

Bench mark	a reference mark of known elevation cut or set in stone, concrete or other durable and used in the determination of altitudes
Data	information or facts about a particular phenomenon
Database	an electronic memory
Electromagnetic	consisting of electromagnetism
Multi spectral	operating in or involving several parts of the electromagnetic spectrum occurring or recurring simultaneously
Parameter	a descriptive property of the population while statistic is a descriptive property of a sample
Population	a group of people, events, things, or other phenomena that you are most interested in; it is often the "who" or "what" that you want to be able to say something about at the end of your study. The set of all elements that share one or more characteristics for which we wish to make an inference
Radar	an instrument which discovers the position or speed of objects such as aircraft or ships when they cannot be detected by using radio signals
Radiometer	an instrument for the detection or measurement of radiant energy
Sample	a smaller (but hopefully representative) collection of units from a population used to determine truths about that population in a research process
Satellite	an object which has been sent into space in order to collect information or to be part of a communication system
Scan	examine it using a machine that can show or find things inside it that cannot be seen from the outside
Sensor	an instrument which reacts to certain physical conditions or impressions such as heat or light, and which is used to provide information

Spectrum	a range of different colours which is produced when light passes through a glass prism or through a drop of water
Trigonometric station	a fixed surveying station, used in geodetic surveying and other surveying projects in its vicinity
Variable	is any characteristic, number or quantity of a person, object or phenomenon that can be measured or counted
Wavelength	distance between a part of a wave of energy such as light or sound
X-rays	a type of radiation that can pass through most solid materials

Bibliography

Abeedulah, J. (1993). *Fundamentals of photointerpretor and photogrammetry*. Winrock International.

Agor, A. (2015). *A Text book of surveying and levelling.* Khana publishers.

Alan Strahler /Arthur Strahler (2006). *Introducing physical geography.* John Willey and sons, Inc.

Burt, J. S. Barber, G. M., & Rigby, D. L. (2009). *Elementary statistics for Geographers* (3rd Ed), The Guilford Press A. Division of Guilford Publications, Inc.

David, P. P., & Kisser J.D. (2012). *Aerial photography and image interpretor* (3rd Ed). John Willy & Sons, Inc.

Durra, S. E. (1990). *Map reading, photograph interpretation and elementary survey.* General publications Ltd.

Durra, S. E. (2003). *Map reading, photograph interpretation and elementary survey for secondary level*. General publications Ltd.

Ferguson, A. G., & Ngau, P. M. (1981). *Fieldwork and data analysis in geography*. Macmillan.

John, S., & Roger, K. (2008): *AQA Geography.* Nelson Thomas Ltd, Delta Place.

Lodha, R. M. (2010). *Academic dictionary of geography*. India Publishers.

Mc Master, D. N. (1970): *Map reading for East Africa.* Longman Group Ltd.

Mc Master, D. N. (1971). *Map reading for East Africa.* Longman Group Ltd.

Murry, A. (1967): *Africa: The study map notes books.* Collins Clear Press.

Paul, P. (1979): *Longman dictionary of contemporary English.* Pitman Press.

Prichard, J. M. (1979): *Practical geography for Africa.*Longman Group Ltd.

Pritchard, J. M. (1990). *Practical geography for Africa*. Longman Group Ltd.

Richard White (1984): *Africa in focus, A physical human and economic Geography*.

Speak, P., & Carter, A.H. (1964). *Map reading and interpretation*. Longman Group Limited.

Truran, H. C. (1975). *A practical guide to statistical maps and diagrams.* East Africa Publishers Ltd.

United Republic of Tanzania (2017). *National environment statistics report,* 2017 Tanzania Mainland, NBS.

United Republic of Tanzania (2018). *National environment statistics report,* (NERSR, 2017)-Tanzania Mainland, Dar es Salaam,Tanzania Mainland.

United Republic of Tanzania (2019). *Dodoma region investment guide*.

United Republic of Tanzania (2019). *Songwe region investment guide*.

Index

H

I

K

L

M

N

O

P

Q

R

V

W