COMPENDIUM OF COMMUNITY AND INDIGENOUS STRATEGIES FOR CLIMATE CHANGE ADAPTATION

WITH FOCUS ON ADDRESSING WATER SCARCITY IN AGRICULTURE

(INCOMPLETE DRAFT FOR DISCUSSION PURPOSES ONLY)

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1  INTRODUCTION

It is necessary to revitalise and support indigenous knowledge systems, to address current challenges such as climate change. Indigenous knowledge are now recognised as critical resource that must be promoted to support livelihoods and food security, often under variable or changing climatic conditions. This document seeks to develop a compendium of community and indigenous strategies for climate change adaptation.

1.1  IDENTIFYING CASE STUDIES

There are several case studies available in literature. However, most of them are barely narrated and the geographic location of the communities vaguely identified. Therefore, the following criteria are used qualify a strategy as a case study to include in this compendium. The criteria are as follow:

1. They include a local/indigenous/community knowledge
2. The knowledge is linked directly to the relationship people have with their natural environment
3. It is part of a body of knowledge and beliefs shared by a group of people (resource users) over time
4. Mainly transmitted through cultural transmission (often orally)
5. Mainly qualitative as it is difficult to measure
6. Does not have to be proven by western science as it is may be based on empirical observation rather than an accumulation of fact – thus makes sense within the context of that particular place, culture or tradition.
7. The knowledge is documented in a peer reviewed publication, grey literature or a website.

1.2  THEMES

The case studies have been classified into the following themes governance, technologies and practices and other. An additional theme deals with the important semantic question.
1.2.1 Theme 1: Technologies and Practices
Objective: to identify and assess the sustainability and replicability/upscaling of technologies and practices for coping with water scarcity in agriculture in the context of climate change.

Topic 1.1. Weather forecasting and early warning systems

Topic 1.2. Grazing and Livestock management

Topic 1.3. Soil and Water Management (including cross slope barriers)

Topic 1.4. Water harvesting (and storage practices)

Topic 1.5. Forest Management (as a coping strategy to water scarcity)

Topic 1.6. Integrated wetlands and fisheries management

1.2.2 Theme 2: Semantics
Objective: to explore the appropriate terminology for the technologies and practices under discussion

Topic 2.1. Terminology: Indigenous Knowledge (IK), Community Knowledge (CK), Traditional Ecological Knowledge (TEK), etc.

1.2.3 Theme 3: Governance
Objective: to identify factors influencing an enabling environment for the adoption of the practices and make recommendations

Topic 3.1. Land Tenure Systems

Topic 3.2. Institutional arrangements (or lack of)

1.2.4 Theme 4: Other practices
Objective: to identify other factors affecting the sustainability of the technologies and practices

Topic 3.1. The Youth’s attitude towards technologies and practices

Topic 3.2. Taboo, cultural, religious and spiritual beliefs

Topic 3.3. Alternative livelihood strategies
1.3 Structure of the Case Studies

To have a consistent narration of the case studies, the structure below was adopted (Table 1.1).

Table 1.1. Proposed structure of the case studies

<table>
<thead>
<tr>
<th>THEME</th>
<th>Technologies and Practices</th>
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</thead>
<tbody>
<tr>
<td>Topic</td>
<td>Weather forecasting and early warning systems</td>
</tr>
<tr>
<td>WHO</td>
<td>Aboriginal communities such as the Nyungar</td>
</tr>
<tr>
<td>WHERE</td>
<td>in southern Western Australia</td>
</tr>
<tr>
<td>WHAT</td>
<td>identify six seasons (Smith and Kalotas, 1985) based of the interaction between meteorological patterns (direction of prevailing wind and rainfall intensity), the flora (flowering and fruit ripening time) and the fauna (animal abundance and fatness).</td>
</tr>
<tr>
<td>VALUE/Meaning</td>
<td>The seasons which are the main determinants of the timing and movement of the communities, assist in the conservation of traditional hunting, fishing and gathering activities. Such activities may enable this indigenous community to enhance their adaptive capacity in the face of a changing climate</td>
</tr>
<tr>
<td>Knowledge</td>
<td>Some aboriginal Australians still rely on a diet of fruits and vegetables, nuts and grains, meats and fish, oils and fats sourced from the bush, the land, waterways and the seas. This knowledge has been orally transmitted through generations.</td>
</tr>
<tr>
<td>Added Information</td>
<td>This knowledge has been orally transmitted through generations, specifically for food gathering such as nuts and grains from mother to daughter, and hunting and fishing techniques from father to son as part of coming of age rites of passage for boys.</td>
</tr>
</tbody>
</table>

The case studies are therefore currently presented per Themes and Topics as indicated below:

**Technologies and Practices**

**Weather forecasting and early warning systems**

*Aboriginal communities such as the Nyungar, in southern Western Australia, identify six seasons (Smith and Kalotas, 1985) based of the interaction between meteorological patterns (direction of prevailing wind and rainfall intensity), the flora (flowering and fruit ripening time) and the fauna (animal abundance and fatness).*
The seasons which are the main determinants of the timing and movement of the communities, assist in the conservation of traditional hunting, fishing and gathering activities. Such activities may enable this indigenous community to enhance their adaptive capacity in the face of a changing climate.

Some aboriginal Australians still rely on a diet of fruits and vegetables, nuts and grains, meats and fish, oils and fats sourced from the bush, the land, waterways and the seas. This knowledge has been orally transmitted through generations, specifically for food gathering such as nuts and grains from mother to daughter, and hunting and fishing techniques from father to son as part of coming of age rites of passage for boys.

As previously alluded, it is very difficult to find all those elements in literature. Thus, for most case studies presented, only few of these descriptors are available.

1.4 Methodological Approach

Literature review was carried out in order to identify cases of indigenous knowledge and practices for climate change adaptation across the Globe. Relevant information in this regard was thus collected. Case studies narrated in this document were obtained from secondary data primarily sourced in peer reviewed literature. Those case studies will be categorised and presented in relation to global agro-ecological zones (GAEZ, Figure 1.1).
AEZ are preferred because they best describe the similarity of conditions between areas under rainfed agriculture. Two approaches were used to associate agro-ecological conditions with the identified adaptation strategies:

- Adaptation strategies are categorised according to their application such as weather forecasting and early warning systems, etc.;
- In most cases, information on agro-ecological conditions of the case study is lacking. Thus, the GAEZ shapefile (FAO and IIASA, 2010) is overlaid with the case studies’ locations to identify their agro-ecological conditions.

Figure 1.1. Agro-ecological zones (AEZs) of the world that will be used to discretise the narrated case studies.
2  THEME 1: TECHNOLOGIES AND PRACTICES

Objective: to identify and assess the sustainability and replicability/upscaling of technologies and practices for coping with water scarcity in agriculture in the context of climate change.

2.1  TOPIC 1.1. WEATHER FORECASTING AND EARLY WARNING SYSTEMS

2.1.1  Weather forecasting and early warning system in Africa

A number of East African communities have adopted various indigenous weather forecasting methods over the years. Most of the methods adopted have either been weather-related forecasting such as observing the colour of the sky and or the use of natural indicators such as observing animals, plants or insects. In Uganda (Hoima, Rakai and Bahima), the visibility of the nimbostratus and cumulonimbus clouds indicates a high possibility of rainfall.

In Ethiopia, (Borana and Afar), the appearance of “white feather like column (vertically standing) cloud in the sky is an indication that the rain is about to come” (CCAFS, 2017). Generally, a sky dominantly covered with light cloud indicates a drought season.

Pastoralists from northern Kenya (Ariaal, Boran, Chamus, Gabra and Rendille tribe) and southern Ethiopia (Guji tribe) observe the speed of wind, movement of stars, the position of the moon and lightening to predict the next rain season (Luseno et al., 2003). Others interpret dreams or even the patterns in which their pair of shoes have fallen on, after it has been repeatedly thrown. More so, observing animal (livestock, wildlife or local flora) behaviour or reading intestines of slaughtered animals such as goats, sheep and cattle, projects the period of a drought, the severity, affected areas, and disease outbreak (Luseno et al., 2003).

In Lushoto, Tanzania, the start of short rains is identified by the occurrence of “large flocks of swallows and swans, roaming from the South to the North during the months of September to November” (Mahoo et al., 2015).

Evidently, indigenous knowledge plays a significant role in enabling local communities to make sense of environmental change, mostly at local level (micro climate). With environmental change taking place, more communities are adapting to weather
changes through indigenous weather forecasting techniques. These techniques have been mainly aimed at predicting seasonal climate change, for instance, the onset of rainfall, which areas will receive more rainfall, and the end of rainfall. These climatic patterns have been important for pastoralists as they are often at “finer” spatio-temporal resolution compared to modern climate forecasts (Luseno et al., 2003). Thus, farmers and communities continue to rely on their own local forecasting techniques as they are grounded in their own experiences. These indigenous forecasting methods therefore, allow communities to adapt in the face of a changing climate.

In the Central Plateau of Burkina Faso, Bonam village, climate indicators used by farmers to forecast incoming rainfall season becomes available for observation at different times of the year, starting instantly after the harvest period until the beginning of a new rainy season. The farmers depend mostly on observing food production trees at the start of the rainfall season and temperatures during dry season. The observation of winds, sky, plants, animals and the behaviour of birds and insects are also a forecasting method regularly used by farmers in Burkino Faso (Roncoli et al., 2002). These prediction estimate the onset date, intensity and the duration of the cold and dry season. Older male farmers tend to be more knowledgeable than younger men or women farmers. However, knowledge differs significantly among the elders. More so, spiritualists, who have inherited powers or acquired skills by virtue of initiation or election by the spirits, hold knowledge that is not available to all (ibid).

In the Makueni district, south-eastern parts of Kenya, the “weakness of poultry, cattle and human beings and the abundance of honey in the hives notifies a drought during the next season (Speranza et al., 2010). Also the appearance of rare birds or insects, nocturnal noise of crickets, quiet frogs and the presence of nimbus clouds in the day and their absence at night indicates a drought period. These observations allow agro-pastoralists to alter their practices if they have prior knowledge of an upcoming drought or flood. As such, their indigenous forecasting techniques allow them to cope and respond to climatic changes, while alleviating its impacts.

Indigenous knowledge has been, and continues to be, used for climate monitoring. The study conducted by Speranza et al., (2010), in south-eastern Kenya, demonstrates the richness of indigenous knowledge and the diversity of indigenous knowledge based indicators for monitoring climate variability and change. As such, various
indicators from flora, weaver birds, weather variables, astrology (constellation of stars), to the environment (shadow of hills), provide a rich store of knowledge (ibid). This is an indication of knowledge that has been passed down from one generation to another, and helps communities prepare in time, for environmental change.

In South-Omo Ethiopia (Dassenech and Nyangatom Wereda), when the Omo River does not over flow to the surrounding flats, a drought and food shortage period awaits (Gebresenbet and Kefale, 2012). However, if the river over flows a great deal, houses, people and livestock could possibly be swept away. Indigenous early warning methods, rely quite a bit on predictions and observations of animal behaviour as it helps many communities prepare for the rise in water by projecting incoming rains and their intensity. These projections help communities take decisions, for example, people will have no choice but to move from the Omo River if severe flooding is expected (ibid). In such instances, the “elderly reach a decision based on predictions made by observing stars, winds and cloud patterns, behaviour of specific wild animals or the flowering of some plants which will be passed to the youth of the group who will then move the herd to a safe place” (Gebresenbet and Kefale, 2012). This early warning system gives the community enough time to move into either safer areas when a flood is predicted or wetter areas in times of drought. Notably, elders with the knowledge or skill to predict weather changes is respected by the whole community.

Pastoralists and agro-pastoralists in south and east Ethiopia are living in arid and semi-arid rangelands (Enyew and Hutjis, 2015). As a result, movement is a key strategy for pastoralists particularly when dealing with sudden rainfall, livestock diseases and sustainable use of scarce natural resources. Pastoralists in Ethiopia face a number of challenges that threaten the sustainability of their traditional practices. Such as trends indicating climate change, such as increasingly recurrent drought, floods, erratic rainfall patterns, and high temperatures are adding significantly to these stresses (ibid).

In the Teso sub-region, Eastern Uganda, the growth of new leaves in January and February indicates the onset of a rain period. This indicates that gardens should be tilled, while others sow millet in the soil, awaiting approaching wet season in March (Egeru, 2012). In the Ngora district, Uganda, rain season was predicted by winds blowing from East to West and the redness of clouds in the East was a prediction of hailstones. The Rakai District in southwestern Uganda, relies on climatic, flora and
fauna indicators to predict the onset of rain season. Warmer temperatures at night time, changes in wind direction, flowering of coffee trees, certain phases of the moon, appearance of whirlwinds that lift dust and leaves and the arrival of the Abyssinian hornbill are indicators of a good rain season (Orlove *et al.*, 2010).

Similarly, in the Upper West region of Ghana, the flowering and fruiting of the baobab, shea and the dawadawa trees is an indication of a favourable rainfall season. The ripening of the fruits especially the shea fruit is also an indication of a good rain season (Gyampoh *et al.*, 2011). In some local communities such as Bankpama (Upper West), Pwalugu and Talensi (Upper East) of Ghana, the visibility of frogs or croaking frogs around March, indicates a good wet season.

In the Jensue community of Western region of Ghana, the formation of a rainbow in the east at dawn indicate that they will receive below average rainfall this season (Gyampoh *et al.*, 2011). Other examples include, information at Enchi community that there has been heavy rainfall in the nearest community, example Adonkrom, this word of mouth approach signifies heavy rainfall and flooding will reach the community in less than 24 hours. Furthermore, the movement of wind and dark clouds and the appearance of sun in the morning indicate the pattern of rainfall in the Aowin-Suaman District in the Western region of Ghana. The Old Yakase community of in Ghana, predict a strong rainy season through the observation of thunder and lightening in March, prior the rainy season. Other communities observe the shedding and sprouting of leaves on trees in particular months of the year, as an indication of the beginning and ending of seasons (Gyampoh and Asante, 2011).

The appearance and disappearance of some migratory birds are natural indicators of the nature of the farming season. For the Jensue community of Ghana, the appearance of the "Brobbey" (bigger than the crow, blue-black in colour and has a strand of feathers on its head like that of the comb of a cock), announces the beginning of the raining season. The bird is said to be “gods announcer” because it comes every year to announce the beginning of the rainy season (Gyampoh *et al.*, 2011). Millipedes and centipedes seen climbing to higher grounds at the start of the rains signal that there is going to be flooding in the community. They are noted to first sense the flooding in the soil and they begin to move out to the higher ground or hills (*ibid*).
The examples above indicate the highly social nature of the knowledge. Communities have developed different means to exchange information that they might not otherwise have access to; helping them gain a firmer sense of the arrival and progress of the rains (Orlove et al. 2010). Moreover, all the components of this indigenous knowledge; the historical patterns, the signs, the weather observations and the regional information, are widely accessible and widely shared. Elders are treated with respect in conversations about weather as in many other settings, and their stock of personal experience is considered to be valuable (Orlove et al. 2010). Notably, although indigenous forecasting techniques have been passed down from generation to generation through “oral history” and local expertise, there remains a wide inter-generational gap between its custodians and the young people (Mahoo et al., 2015).

For the Dzelukope community of Ghana, hot weather from January through to April is an indication of a good rainy year. The degree of hotness of the ground an indicator of a very heavy rainy season (Kpadonou et al., 2012).

Farmers in the South-Western Free State often experience climate and weather related disasters, such as droughts, floods, untimely frost events, severe and persistent winds that intensify dangerous wildfires, outbreak of diseases and pests that severely affect their farm output, as well as overgrazing that poses dangers of soil erosion and land degradation (Zuma-Netshiukhwi et al., 2013). These farmers rely on weather and climate linked indicators to predict immediate seasonal rains and droughts, including observing animal and plant behaviour, as well as observing other climatic elements. For instance, they use budding of acacia Karoo and sprouting of Aloe ferox in the mountains as an indications of coming good rains. In September, flowering of wild lilies in the veld and dropping of fig tree leaves (Ficus carica) is an indication that summer is approaching (ibid). Also, immature fruits drying on the trees and dropping between September and October is an indication of drought. These traditional farmers use these indicators as a guidance for agricultural activities to be undertaken.

Similarly, farmers in the Karoo (Beaufort West, Prince Albert and Oudtshoorn region), Ganyesa Village of North West province (Tlhompo, 2014 Ncube and Largedian, 2015) observe the fauna to predict weather conditions. For instance, calves running and playing in the field in the Karoo (Beaufort West, Prince Albert and Oudtshoorn region and in the South Western Free State is an indication that rain is coming in few days
Moreover, in the Karoo and in the South Western Free-State, black ants (*laisius niger*) collecting and storing food, the presence of red ants and a rapid increase in size of moist anthills, the appearance of reptiles like snakes moving up and down in the mountains between August and September, appearance of red dominated rainbow colours between June and July as well as increased libido in goats, predicts good rains. Similarly, in Mogalakwena community in Limpopo Province if the cattle herd hesitates to go to the veld for grazing, within a few hours there will be rains (Rankoana, 2016). Consequently, farmers starts preparing for a growing season. Furthermore, grunting of pigs indicates low humidity and increase in temperature in the South Western Free state. The presence of tortoise (*chersina, angulate*) is an indication of thunderstorm (Ncube and Largedian 2015).

Mogalakwena community of Limpopo Province, South Africa at the beginning of September month, the Senegali plant species produce yellow flowers which according to the local people indicate a start of a good season with approaching rainfall nonetheless if the flowers are deep-yellow, pale flowers thus predict limited rainfall (Rankoana, 2016). Additionally, the appearance of *tsie* (edible insects) in greater numbers in spring in that community signifies shortage of rain in the next season.

### 2.1.2 Weather forecasting and early warning system in America

In Incas, Peru, observations of the constellations, phases of the moon as well as the salinity of raindrops are used to determine weather and climate (Eakin, 1999).

In Tlaxcala, Mexico, animal behaviour, sky appearance and astronomical observations are used to forecast weather. Ants flying away of underground nests are used to predict wind direction; while, the height of swallows' flock are used to predict rain events. Drop in temperature and thin clouds are indicators of frosts; while, high black thick/puffy clouds with white peaks are indicators of hail storms. Moon phases are also used for rain and dry day predictions (Eakin, 1999).

In Tlaxcala Mexico *El Galvan* (Mexican equivalent of the farmer's almanac used in the United States, except that it is based in the liturgy of the Catholic Church) and *Cabănuelas* (relatively informal system of environmental observations that is used to anticipate general climate conditions for a whole year) are methods used by farmers
to forecast weather (Eakin, 1999). *El Galván* was founded in 1826 by Don Mariano Galván Rivera and is now published annually by a press in Mexico City. While; the origins of the *Cabánuelas* system possibly could be traced to the conquistadors as the system seems to have little to do with the climatic patterns of particular localities. These practices, which are passed on to present generations of producers are increasingly abandoned. The new generation perceive them as complex, time consuming (*Cabánuelas*) and expensive (*El Galván*). Furthermore, they are seen as less reliable because of the increasing climatic variability.

Indigenous knowledge continues to play an important role in the way communities interact with their climate in many countries, particularly in Bolivia. It contributes to weather forecasting at the community level, and to the preservation of vital ecosystem functions that help to shield communities against climate change impacts. However, the increasing incidence of extreme weather events and disasters is taking a toll (DeAngelis, 2013). Over generations of observing their environment, Bolivia’s indigenous people have adapted a unique body of knowledge that helps them adapt to the effects of climate change through weather predictions and coping strategies (Kronik and Verner, 2010). The Chipaya people for example, monitor the wind, clouds, frosts and other signals to predict the weather and improve agricultural practices (DeAngelis, 2013).

### 2.1.3 Weather forecasting and early warning system in Asia

Asian communities are tremendously vulnerable to natural disasters such as droughts and floods. Archipelago and small Island states of Southeast Asia are particularly vulnerable to the impacts of hydro-meteorological hazards (Hawasaki *et al.* 2014). Different communities use diverse mechanisms and indicators to predict weather conditions. Before the use of the modern scientific methods for weather forecasting and climate prediction, farming and other livelihood pursuits were sustained by traditional knowledge (Rautela and Karki, 2015). Traditional local communities continue to rely heavily on their indigenous knowledge systems to adapt to climate variability.

Villages located in the Johar, Byans, Bhagirathi and Niti valleys of Higher Himalaya in Uttarakhand (India), forecast weather using bio indicators and physical factors such as wind direction, time of the year, colour of sky and position of stars (Rautela and Karki,
By closely observing the behavioural change of their natural environment, they predict the present and future events like weather (Mishra, 1998).

In the Houldari village of South Andaman district (Andaman and Nicobar Islands of India), the appearance of certain birds, the mating of certain animals and the flowering of certain plants are all seen as important signals of change with respect to timing and seasonality of natural phenomena that are well understood in traditional knowledge systems (Sethi et al., 2011). The fruiting of peaches (Prunus persica), apricots (Prunus armeniaca), figs (Ficus sp.) or the budding of certain trees in the farms is an indication of the onset of spring; while, the emergence and growth of new leaves indicates that the temperature is increasing and the winter season is drawing to an end (Rautela and Karki 2015). If rainbows appear in the east there could be a drought but if it appears in the west there will most likely be good rains (Sethi et al., 2011). The luxuriant growth of forest vegetation indicates an above average rainfall season. If rainbows appear in the east there could be a drought but if it appears in the west there will most likely be good rains (Sethi et al., 2011). The luxuriant growth of forest vegetation indicates an above average rainfall season. Snail climbing certain trees, earthworm crawling, ants shifting to safer places and insects flying around, presage a cyclonic weather followed by heavy rain (Sethi et al. 2011). Redness in the sky after sunset also indicates cyclonic storms/ disaster within seven days.

In Rajasthan (India), the appearance of butterflies indicate early rainfall onset and gives an indication of a good season (Pareert and Trivedi, 2011).

In villages of the Aizawl (Tanhril, Muthi and Seling), Champhai (Champai ngaizwal and Hnahlan) and Saiha (Saiha, Teiva and Tuipang) districts, state of Mizoram (Northeast India), the experiences and knowledge passed through generations continue to play a vital role to the sustainability of the communities (Chinlampiamga, 2011). These communities use different indicators such as birds, insects, fish, plants and clouds to predict weather and seasonal conditions. When male bamboo partridge roar frequently during spring and summer in the morning after sunrise, rains is expected. On the contrary, when it rains in the morning, the roaring of the bamboo partridge indicates that the rains will stop. Furthermore, when there are several ants moving along a path carrying their food items with them, a heavy rain is expected on the same day (Chinlampiamga, 2011).

The Intertropical Convergence Zone increases the rain intensity and thunderstorm in Philippines area, triggering flooding and other natural disasters to which, many communities are extremely vulnerable (Hawasaki et al., 2014). For centuries, these
communities have developed mechanisms to survive natural hazards. With climate change vulnerabilities *bayanihan* (collective action of people to assist those in need) is used by a number of communities in the Philippines in times of emergencies and disaster (Hawasaki *et al.*, 2014). Indigenous knowledge have also played a key role in climate change adaptation strategies of these communities.

The Ilocos Norte (Philippines) community relies on their traditional knowledge to predict short, medium and long-term weather changes. To forecast weather condition, atmospheric and astronomic phenomena, plant phenology and animal behaviour are observed. The farmers predict rainfall by observing clouds; when clouds near the sun look reddish at dawn and when it is cloudy in the east or the west, it will rain. Furthermore, rain is expected to fall within a day or two when the moon and stars are seen dim and a rainbow appears in the morning (Galacgac and Balisacan, 2009). This knowledge enables farmers to timely plants suitable crops and gives them time to prepare for the occurrence of harsh weather conditions such as thunderstorms, floods, typhoons, and even droughts (Galacgac and Balisacan, 2009).

Traditional phonological indicators assist people in Tripura (Northeast of India) in planning for agroforestry and disaster prevention. Thus, the phenology of the night flowering jasmine (*nyctanthes arbor-tristis L.*) is used to predict the beginning of heavy rainfall events (Archarya, 2010).

The indigenous Pagu and Gura communities in Indonesia have their own ways of predicting imminent dangers (Carling and Sherpa, 2015). The sudden low tide with strong smell of salt from the sea, the emergence of bubbles in large quantities followed by a loud roar from the sea and high-black and long waves, signal the impending danger in the island. Whoever sees these signs, will hit the Toleng-toleng (a communication tool made from bamboo/iron and knocking) to warn others of the impending Tsunami. The same communities use the signs of nature and animal behaviours to determine the changes in the season. This is called “*nanaku*”, which is the knowledge to predict an event based on their past experiences. Accordingly, the coming of the Korehara birds (local name) to the mangrove area on the islands of Kumo, Tagala and Kakara, is a sign of change of wind direction (wind is blowing from the south) and the beginning of the rainy season. The coming of the Maleo bird (*Macrocephalon maleo*) signals the change of the sea water level. The typical voice of
this bird indicates the significant changes in the sea level. Also, the migration of *Luo-luo* birds (local name) to the mangrove on the island of Kumo and Kakara suggests the abundance of fish in the sea. These birds come to the islands to find food (fish). People often use these signs to find species of fish that will be caught in the sea. Similarly, “*Mangele*” is the knowledge to observe the position of clouds above the Mount Dukono, which is an active volcano. According to their reading, if the clouds are straight, thick and covers the top of the mountain, it is an indication that there will be big waves, strong winds and very strong currents. People must not go fishing during these conditions.

For the Tangkhul community (North East India), the appearance of giant earthworms after a dry period is a sign of rain (Carling and Sherpa, 2015). The communities predict drought by the behaviour of animals that live in burrows such as the erratic appearance of the Pangolin towards the end of winter or beginning of spring as a sign of drought or late monsoon, and the content of moisture level in their burrow as a sign of good rain. The annual climatic forecast of the community is done by observing the weather pattern during the seed sowing festival, which falls towards the end of January. Their prediction is more related to the average weather conditions like the optimal rain that will result in good harvest, drought or changes of rain pattern that will disturb the plantation period or flowering period of their crops.

The Karen communities (Thailand) predict earthquakes and floods by observing the behaviour of cats and dogs (Carling and Sherpa, 2015). If cats run in an unusual way, there will be an earthquake. If the dogs run in total chaos or they walk in an unusual way, these are hints to the indigenous peoples living close to the river that there is a potential flood is coming.

### 2.1.4 Weather forecasting and early warning system in Oceania

In Oceania there are some similarities in methodologies used to predict weather conditions such as observation of seasonal change, identification of cloud formations, changes in animal and plant behaviour as well as other natural environmental changes.

Over centuries, indigenous communities of Oceania developed an appreciation of their local ecosystems and its climatic variation. They still rely and live closely connected to their natural environment. Indigenous knowledge is therefore highly valued by these
communities, as it is used to inform decisions in planting, fishing and hunting as well as other seasonal dependent events such as (Green et al. 2010).

The Baada, commonly called the Bardi, an indigenous community of south-west Kimberley (Western Australia), has a concept of seasonality more complex than that of a two-fold Wet-Dry pattern (Green et al., 2010). They recognise six seasons, distinguished mainly by wind and rainfall direction and intensity, ripening of fruits, and appearance, disappearance and ‘fatness’ of fish and animals. Mangal is the Wet, the rains, the monsoon season, characterised by strong winds and storms from the ocean (ungulungul) and whirlwinds (adjibangur). People shift away from the coast to the inland during periods of heavy rains, staying in paperbark shelters (gidun). Ngalandany is the end of the Wet, and literally means 'no fruit'. Temperatures and humidity are high, there is no wind, and during this 'rubbish time' people move around as little as possible. Iralbu is the period of king or big tides; the low tides are ideal for reefing. There is much fruit available such as the ngurngulu (Avicennia marina) fruit, which indicates that it is time to shift camp to beaches and high dunes to avoid mosquitos. Bargana is the 'cold' season when people start to light night fires. This is the hunting and fishing season through though tides.

The Wurdeja, Ji-malawa and Yilan of central north Arnhem Land in Northern Australia Aboriginal communities of central north Arnhem Land, have developed a calendar with four seasons that are based in language and cultural activities, each season has its own patterns of winds and weather, plant growth and cycles of animal life and death. This knowledge assist these communities in knowing the right time for activities such as hunting and gathering, burning and ceremonial life. For example, 'when the leaves of the yam plant change colour, the communities knows it is time to burn the bush to clear the land for new growth (Green et al., 2010).

Miriwoong people in the East Kimberley of Western Australia break the year into three distinctive seasons: Nyinggiyi-mageny (wet season), followed by Warnkamageny (cold season) and then Barndenyirriny (hot season). To predict seasonal and climatic changes, animals and plants behaviour are observed. In the Keep River, for instance, Miriwoong people observe that the flowering of the Gali-Galing (Fern-leaf grevillea) indicates the beginning of the cold season, and good time to undertake tradition
burning practises to prevent late hot season fires that damage the landscape (Green et al., 2010).

The Aboriginal people of north-east Arnhem Land (Australia) also recognise six seasons, each of which is clearly identified by distinct changes in the flora, the fauna and climatic conditions. Similar traditional knowledge involving observing ocean color, waves, and wind is used to predict extreme weather conditions in the Pacific Islands (Nakashima et al., 2012).

The cabbage tree/tī kōuka is common throughout farmland, open places, wetlands and scrubland of the North and South Islands and it prefers full sunlight, Consequently Aotearoa people in New Zealand, observe flowering of this species. Early and profuse flowering of Tī kōuka Cabbage tree is an indication that a hot summer should be expected.

In Vanua Levu, Taveuni, Kioa, Qamea, and Rabi Island, Fiji to predict heavy rainfall or strong winds, communities carefully observe clouds, waves, winds, sun, and the stars. For instance, for clouds, changes in texture (thin or thick), color (white, dark, yellow or red), location (over mountains or the sea), and movement (to/from the coast), including speed (fast) and direction (vertical or horizontal) are observed (Janif et al., 2016).

In both Rapu-Rapu, Philippines and Aceh, Indonesia, a foul odour emanating from the sea signified the coming of a storm or typhoon.

In the East Kimberley of Western Australia, when (Fern-leaf grevillea) Grevillea pteridifolia bears its bright orange flowers Miriwoong people know the cold season has arrived (Green et al., 2010).

Animal, insects and plant behaviour are also used to predict weather conditions. In Vanua Levu, Taveuni, Kioa, Qamea, and Rabi Island, Fiji excessive fruiting of breadfruit and mandarin (Citrus spp.) is a signal of the approaching extreme weather conditions (Janif et al., 2016). When hornets start building their nests closer to the ground than usual, it is a sign that a tropical cyclone is imminent.

In Raimea and Lau-Hata, Timor-Leste, leaches and caterpillars are noted as appearing before storms. When banana tree leaves and branches of other trees fall to the ground
without strong winds, people in Rapu-Rapu, Philippines prepare for storms or typhoons (Hawasaki et al., 2014).

Birds, usually migratory, are important indicators of changing seasons and their duration, as well as heavy rains, storms, or droughts, in Raimea and Maluru-Beaço, Timor-Leste, and Sayung and Lipang, Indonesia. In Perez and Rapu-Rapu, Philippines, various animals are used to predict hazards: rays jumping consecutively in the sea in summer, the fast movement of sea snakes, and hermit crabs going inland or climbing up trees all forewarn storms or typhoons (Hawasaki et al., 2014). These observations are also considered indicators of other hazards such as landslides and flooding, since they often take place after heavy rainfall and strong winds. In Rapu –Rapu island, Filipinos when branches of tree such as (gmelina ta lisay, pili and marukbarok, tamarind santol, narra) and banana leaves fall on the ground even when there is no strong wind, in two days there will be heavy rains, storm surges or strong winds. In Vatulele Island when the central unfurled leaf (uvu-na) of the vudi plant bent down rather than pointing straight up is an indication of bad weather, perhaps a tropical cyclone is approaching even weeks in advance.

The coastal and small island communities have long histories of observing changes in the environment and have a collective wealth of knowledge and practices closely related to these changes, local knowledge has been used to devise traditional seasonal calendars, these communities have also developed traditional mitigation and adaptation strategies for climate change (Hawasaki et al., 2014).

Indigenous communities in Papua New Guinean have experienced a range of disasters, these communities have employed a number of strategies to cope the impact of climate change. Traditions and practices have influenced the way local communities forestall, and adapt to extreme weather events (Sithole et al., 2015). For instance, the communities observe different environmental changes thus enable them to employ appropriate strategies. In Popondetta Papua New Guinean, cold breeze or thunder roars coming from the mountains are signals for a cyclone or heavy flood approaching, while; in Bulolo, cyclones are announced by the appearance of a rainbow, while wave noises are associated with tsunamis (Sithole et al., 2015). In addition, in Bulolo and Labu, Morobe when the leaves of the Xuc tree start falling between November and
December signals Drought, while in Popondetta, Oro if flora blossom in a certain colour and flowers fall from trees thus signals dry spells.

2.2  

**Topic 1.2. Grazing and Livestock Management**

Across the world, pastoral communities are making use of their “in-depth knowledge” of indigenous rangeland assessments techniques, which inform their land use arrangements. Each day, herders monitor and observe the condition of rangelands and thereafter decide grazing for their “multi-livestock species” (Homewood and Rodgers, 1991; Cotton, 1996; Mills et al., 2002).

2.2.1  

Grazing and livestock management in Africa

In northern Tanzania, Maasai herders make use of “socio-cultural folk systems, soils, topography and vegetation, management knowledge and seasons of grazing” to identify seasonal grazing lands. The herders have developed a method that characterizes degradable land from non-degradable, in response to heavy grazing pressure (Oba and Kaitira, 2006). The method is used to help the herders regulate seasonal grazing for different landscapes. Significantly, the degradation now observed in the Selela landscapes (Tanzania) was a result of traditional grazing systems being changed by crop cultivation. Past experiences have been used to determine a shift in plant species composition and the disappearance of “key forage species” and an increase in species less desired by livestock were used as indicators of degradation (Oba and Kaitira, 2006). The landscape interpretation reflects strong cultural values and special experiences, while emphasis on the ecological purpose of grazing. More so, the interpretations of landscape change has helped the Massai herders monitor environmental change.

In the Central Plateau of Burkina Faso, Bonam village (Mossi tribe), certain trees are significant for predicting seasonal rainfall and guiding agricultural activities. When the sigba tree starts to bear fruits and the sabtuluga tree loses its leaves, farmers know, the time to plant has arrived (Roncoli et al., 2002). Moreover, the kanganga tree grows along a water table, near the soil surface which indicates where the herders should dig wells to provide water to their livestock and where they can plant water demanding plants such as cotton (Roncoli et al., 2002). The ability to observe trees allows farmers and communities to manage the impacts of a changing climate.
A traditional water conservation method of Central and North Darfur (Reij et al., 2013) that involves harvesting runoff water by constructing low earth bunds called trus (tera, singular). The technique probably has its origins in the home garden (jubraka) operated by women growing quick maturing crops and some vegetables like okra, pumpkins and cucumbers. When villages grew in size and more livestock were kept at home, women began to extend jubraka activity to areas away from home. This practice became important in recent years, as rainfed farming on sandy soils had become increasingly risky and unable to produce sufficient food for families (Osman et al., 2006).

The Tin Aicha and Ras El Ma Communities of northern Mali have also developed different practices for adapting to environmental changes and climate variability (Brockhaus et al., 2013). Adaptation strategies remain centred around livestock and agriculture activities. The most important strategy for adult men is the “transhumant livestock husbandry (cattle, sheep and goats). They describe this as the “the soul and the proud of a Tamachek pastoralist” and a chance to be a part of a larger social network aimed at reducing climate variability because of “heterogeneity of rainfall and fodder” (Ibid).

In Niger, the Tuareg nomads have protected and improved their pastureland through pasture-management associations; thereby strengthening the resilience to both climatic and non-climatic pressures (New Agriculturist, 2009).

The Turkana pastoralists in northern Kenya, and Sukuma agro pastoralists in Shinyanga, Tanzania, have restored degraded woodlands through the revival of local institutions for natural resource management (Barrow and Mlenge, 2003). The Turkana restored over 30 000 ha and the Sukuma 250 000 ha of woodland; which has resulted in a mitigation of risks associated with droughts (Barrow and Mlenge, 2003).

In the Ethiopian Borana rangelands, pastoralists have retained their nomadic ways but are replacing their cattle herds with camels, which feed on trees as well as grasses and can survive longer periods without water. For other pastoralist groups, adapting involves adopting alternative livelihood options, although income-generating opportunities are often limited in remote dryland areas. Lack of market access for adding value to livestock products is a common constraint (New Agriculturist, 2009). In the long-term it is possible that pastoralists may even benefit from climate change.
In West African Sahel, changing from cattle to sheep and goat husbandry has proved to increase the resilience of communities in regard to adverse climatic conditions during dry periods and droughts for pastoralists and agro-pastoralists. Nomadic mobility reduces the pressure on low carrying capacity grazing areas through the circular movement from the dry northern areas to the wetter southern areas of the Sahel and continuously from South to North when conditions improve (Nyong et al., 2007).

In the Mossi region of Burkina Faso, most farmers during the dry periods fattens their animals especially old oxen and bulls in other to ensure good market prices (Barbier et al., 2009).

In southern Ghana, erosion is controlled by redirecting gullies from farms to avoid flooding (Yaro, 2010). It is common to see small channels and gutters made in most farms and also around the communities. This is to ensure that the flood waters do not stay in the communities and farms for long (ibid). Planting cocoa seedlings closely with small intervals to ensure the survival of some when others are unable to survive is another method used in southern Ghana. This strategy helps early cocoa plants from the direct heat of the sun, farmers raise plant shading trees to cover these cocoa plants. Planting of minor crops such as cashew, tomato and tiger nut to reduce the level of risk rather than traditional crops such as cocoa and oil palm (Yaro, 2010). Diversification, adapting planting dates, and changes in crop varieties planted are important adaptive strategies. These are strategy important in all the zones as a realistic adaptation strategy. Coping strategies buy time for people to effectively plan the future based on the past and imagined scenarios of what trends will occur (ibid).

As environmental change has already affected their livelihoods in the past, in many cases indigenous peoples have developed specific coping strategies to extreme variations of weather. Such as changes in food storage methods, such as drying or smoking foods according to climate variability and corresponding availability of food (Macchi, 2008). Crop diversification in order to minimize the risk of harvest failure (many varieties of crops with differing susceptibilities to droughts, floods, pest etc. are grown). Some of these varieties are adapted to different environment/field locations (near rivers, high on mountains, close to a primary forest etc.) (ibid).
In Tanzania, sustainable grazing on slopes is a special practice of the Maasai pastoralists (Mapinduzi et al., 2003). The presence of more trees than grass is an indication that an area is not suitable for cattle grazing. Such an area is however suitable for small ruminants grazing.

Collective, sustainable management of rangelands is one of the strategies use by many rural communities of South Africa. In Bergille, KwaZulu-Natal, the management of stock and land resources is governed by Traditional Authorities (Hart and Vorster, 2006). In the Karoo, Western Cape, farmers create camps to conserve grazing lands, destock or migrate animals to better grazing lands (Ncube and Largedian, 2015). Stock reduction, shifting of stock to higher carrying capacity camps, and supplemental feeding and water provision are the key strategies employed by farmers in Southern Africa, for instance in KwaZulu-Natal during the summer months, farmers farm on the highveld, and move with their animals to the lowveld and during the winter months when it becomes very cold in the highveld and only the unpalatable sourveld remains (Jordaan, 2011).

As in many other parts of eastern Africa, livestock are an important component of the agricultural system in the Tigray highlands (North Ethiopia). In the crop-growing season, transhumance is practiced on a broad scale in the open-field areas of Tigray, as farmland and stubble can no longer be accessed by livestock (Nyssen et al., 2009). Transhumance is a livestock production systems where the herd is moved between fixed points and following precise routes, to maximise the seasonal availability of grazing resources over a year.

Herds in the village of Adi Geza’eti (2580 m) are brought each summer to the gorge of the River Tsaliet (1930 m), where riparian vegetation exists. The young shepherds establish enclosures and places to sleep, if possible in rock shelters, but if not, in the open air. The first to arrive choose the best places. The shepherds remain there until after the harvest, when the oxen are needed for threshing operations and when the herds are fed by stubble grazing. As this takes place during summer school holidays, young boys who are in school join with those who are not. This is the most frequent method of practicing transhumance in the area.
In Kokolo village (2060 m), the herds are taken to the Geba River valley (1680 m). This case is very similar to the previous one, with the exception that one of the village families has chosen to dwell in the valley and has occupied the best rock shelters and transformed them into permanent cattle sheds.

The villages around Mount Kemer (2440 m) in the Gueralta plain have different livestock migration patterns, depending on accessibility to the mountain, which is composed of a foot slope, a very high cliff, and an undulating top plateau. From Korkor and Da Tsimbia (2000 m), the herds are led toward the upper slopes of Mount Kemer (2200–2300 m), where the land is too rugged to be occupied by farmland. During the rainy season, there are many water holes and there is much lush vegetation. Whereas the herds from Da Tsimbia usually return to the homesteads for the night, those from Korkor have to be taken through a difficult mountain pass and hence are kept overnight on the grazing lands.

The flocks belonging to the slightly urbanized Megab (2050 m) are only taken to the foot slopes of Mount Kemer, reportedly because many farmers have off-farm income activities that do not allow for careful follow-up of livestock in transhumance. People from this area do not bring the livestock to the lowland areas more to the west, as they maintain that the land belongs to other villages.

The herds of Agewo (2840 m) descend the western escarpment of the Rift Valley, which is a day’s walk. This is a region with seasonal springs, and it is much less populated. It is a shared territory in which Afars and Tigrayans are involved in both intensive and extensive interaction. Livestock are kept there throughout the rainy season by adult men: conflicts with the Afar are not frequent, but memories of past fighting and cattle raiding are still recalled.

Hidmo (1450 m), a village in the lowlands with high temperatures and water shortages, is located some 9 km from Tekezze River, one of the major tributaries of the Nile. The river flows in a deep gorge, the slopes and shoulders of which are used as a Transhumance Destination Zones. Rangelands are much wider across the river on its west bank, and the inhabitants have developed a bimodular transhumance system. Throughout the dry season livestock are herded across the river to Chow’eh, an area in the Amhara region, a day’s walk from the village. The flocks are herded by adult men on a rotational basis, but not by children, as Chow’eh is far from home and both the
river crossing and the livestock watering are unsafe owing to the presence of crocodiles. In addition, many children have started to go to school in recent years and dry season transhumance here takes place in the middle of the school year. The magnitude of transhumance in the dry season depends on the previous year’s harvest: when there is little straw, most people will bring their livestock there. Otherwise, only half of the households participate in transhumance. Conflicts with the Amhara cultivators on the other side of the river are rare. In the summer rainy season, livestock are herded on the eastern, nearby banks of Tekezze River, which at that time is impossible to cross. The shepherds are young boys, and the practice is very similar to the one described for Kokolo and Adi Geza’eti. On the left bank of the Tekezze, the Amhara also bring their livestock down to the river. They never need to cross, as there is more grass on that side.

As far as can be remembered, people from Antshel have never practiced transhumance. Until some 12 years ago, livestock were taken daily for grazing to Bereha Antshel, the 250-m high escarpment that overlooks the village, and brought home in the evening. In recent years, these slopes have become exclosures and the area has changed dramatically. Vegetation has grown, infiltration is enhanced, and springs have developed. As every potential rangeland area has become an exclosure, livestock are kept in and near the homesteads; grass is cut from the closed areas and pure water is available in newly arisen rivulets.

In Gobo Dogu’at (2690 m) and Gabien, separated by a 200-m high cliff, livestock are not subject to transhumance. The herds of Gabien village are kept there, feeding year-round on edaphic grasslands on the wetlands in the center of the village. Gobo Dogu’at’s livestock are taken down daily to the valley in the lower part of the village near Gabien. Despite the fact that an ancient, man-made foot tunnel provides access to bushy areas in the west, livestock are not sent there because, it was reported that those areas belong to another village.

Though located in a situation on the Rift shoulder is similar to Agewo, the farmers of Akeza do not take their livestock down the Rift Valley escarpment, simply because there are no areas with sufficient availability of water. Previously, a few springs and some pond water in the rainy season allowed livestock to be kept in the village. Transhumance started only in recent years, after the Hashenge earth dam and reservoir
were built in 1997 within the plateau, some 5 km from the village. Presently, around half of the village stock is brought there during the rainy season and remains there the whole season, herded by children.

In the Guji zone, south Ethiopia, farmers combine livestock and crop production to diversify household income and adapt to drought conditions. Traditional grazing land management practiced include *kaloo jabi*, which is a form of enclosure used mostly for calves (Abate, 2016). Communal enclosures, controlled by *Abbotti Dedha* (the elderly people), are accessible to all members of the community when feed resources are depleted in the communal grazing areas during the dry season. These communal enclosures, located around homesteads and farmlands, are predominantly used for feeding lactating cows, calves and weak or sick animals during the dry season. Communities from the Guji zone have two categories of grazing landscapes, the *Badaa* and the *Gamoji*, which used a combination of climate (rainfall and temperature), soil, vegetation and topography (Abate, 2016). The *Badaa* landscape is characterised by prominent amounts of rainfall, cool temperatures, highlands and dense vegetation cover. This landscape, dominant in the Wadera and Gorodola districts, is used for dry season grazing. The *Gamoji* landscape experiences low rainfall patterns, warm temperatures, lowlands, and scarce vegetation. This landscape, commonly found in the Liban, Wadera and Gorodola districts is mostly used for wet season grazing and. In the Liban district the Didi Liban grazing land, a dry season grazing land, supplied perennial grasslands, water sources and *hayya* soil which is important for livestock production and grazing land management.

One of the common practices used by the farmers is diversified herd composition and division of herds depending on animal species and class. Some farmers separate their herd into *warra* herds (village based) and fora herds (satellite herds) (Abate, 2016). The *warra* herds consist of calves and small ruminants which are kept around the homestead, as were animals under production (lactating cows), sick animals and calves during the dry season. Whereas the fora herds which comprises of heifers, bulls, camels and dry cows, use pastures and water remote from the homestead during the wet season. During the dry season, animals are moved towards water points and use forage resources found at Meta Tika. Furthermore, farmers also practice seasonal herd mobility. The extent and direction of movements is determined by the availability of
rainfall, water feed and security. During the dry season livestock (bulls, heifers, cows, camels, sheep and goats) are moved to remote sites where feed and water are abundant. Household heads and boys (15 years of age) are responsible for the migration of the animals.

Farmers from the Somali region of eastern Ethiopia, use traditional grazing times for their animals (Kassahun et al., 2008). From 06:00 – 12:00 and 14:00 – 18:00, animals resting in the shade of trees grazed from 12:00 – 14:00. Each animal is randomly selected to graze for four weeks. Observations are recorded for four hours each day (two hours before noon and two hours after noon) per animal. This is done at a 5m distance from the animal using binoculars.

In the northern Kunene Regon of Namibia, the Himba community herders jointly manage natural resources like rangeland and water. They apply a seasonal-dependent rangeland use, and conservation of reserves for drought periods (Müller et al., 2007). In the rainy season, the livestock graze on the grass around the households to allow communal rangeland to recover. Herdsmen also hold back some areas for drought in order to manage very low rainfall and fodder production. These reserve areas which are not easily accessible, are located far from water sources. Herdsmen can only access these pastures in cases of emergencies during drought periods. This traditional practice is increasingly disappearing. Because of the heavy impact of grazing throughout the year, rangelands were dominated by annual grasses and herbs and the dry season pastures were mostly covered by annual grasses (Schimdtia kahahariensis). In areas where grazing was not practiced, perennial grasses, mainly Stipagrosis uniplumis dominated on both rainy and dry season pastures (Müller et al., 2007).

Many pastoralists worldwide use management strategies where pastures are rested during the rainy season for use in the dry season (e.g. Turkana of Kenya and Jie of Uganda) (Müller et al., 2007). During the rainy season, productive areas are used, where water is only available temporally. Turkana pastoralists use some of the least productive rangelands in the rainy season and moderately move to areas of higher productivity as the dry season begins (Müller et al., 2007).

Herd splitting is a practice that involves the separation of livestock into distinct herds based on their sex, type, age and productivity. Rendille pastoralists of Northern Kenya,
between the Marsabit hills and Lake Turkana regularly separate large ruminants from small ones, as it is done by the Twareg of Niger (Niamir, 1991).

In the Fulani of north eastern Senegal and Dinka of Sudan, livestock are separated into a milk herd (mainly milking and pregnant animals and their young) and a main or dry herd (Niamir, 1991). Herd splitting increases niche specialisation and reduces competition between livestock for the same feed, and reduces grazing pressure as each livestock is placed in pasture which best suits it. Therefore herd splitting and diversity are practices used to conserve long term productivity of pastures and improve degraded pastures.

Zaghawa herders of eastern Chad use traditional range management practices such as moving their sheep and camels between the north and the south (Niamir, 1991), except, during drought periods.

Pokot herders of Kenya use areas with termite-resistant grass during the wet season in order to conserve good fodder for the dry season. Home-based herds (goats, calves (lukuyan), lactating cows (obre), and sick animals) are left at home during the dry season grazing movements. Dry season grazing areas consist of perennial grasses with permanent water sources, on the hills. Pastoralists move to these areas as soon as surface water sources in the lowlands dry up and forage has been depleted; usually in June and January. The lowland areas provide wet season grazing for livestock and are dominated by annual grasses. Furthermore the Pokot farmers use mixed species herds (goats and camels) as assurance against droughts (Nyariki et al., 2005), because they are more drought resistant than cattle.

Maasai herders broaden their grazing radius and delay entering dry season areas by using donkeys to transport water into grazing areas.

The Wodaabee, also known as the Mbororo, are a small subgroup of the Fulani ethnic group use lunar cycles to schedule livestock movements to new pastures. This leads to moving grazing areas every two to three days (Niamir, 1991). Although the system is common to all the Fulani communities, it is particularly implemented by the Wodaabee herders. The Fulani of northern Nigeria move grazing areas at least four times each season to prevent over use of pasture.
Herders closely observe their livestock an environment for signs that indicate the need to move (Niamir, 1991). For example, the Wodaabe farmers observe livestock faeces, milk yield, animal weight and the amount of cows in heat to assess the quantity of forage. Farmers in Fulani of Mauritania evaluate range quality by taking the livestock to the same pasture on an experimental basis for seven consecutive days. During this period soil types, presence or absence of key forage species, livestock behaviour (sleeping pattern, eating schedule, and hair and skin quality), as well as the presence or absence of wildlife are examined. The Samburu farmers observe grass and browse availability.

In some ecological zones, rotational grazing practices are used (Niamir, 1991). In Fulani of northern Sierra Leone, farmers overgraze one area for 2-3 years then move to a different place and rest the first grazing area for 15-20 years. The Sukuma, south of Lake Victoria do the same but allow a rest period of 30-50 years. However, not all ecological zones are resilient to overgrazing, such as the Fulani of Nigeria where farmers send their excess livestock to neighbouring territories.

Orma herders, eastern Kenya, also apply the seasonal rotation grazing system between landscapes. They achieve it by managing grazing movements between the different Mata dedha associations (elder councils of grazing associations) during different seasons. The wet season grazing landscapes are utilised throughout the rainy season when the rain pools are full of water. Immediately after the pools are empty, the communities return to their traditional dry season grazing lands (the river floodplains of the Tana River and the delta). As soon as the rains resume, the livestock is returned to wet season grazing lands. The Orma’s indigenous knowledge of range movement is determined by soil type and vegetation. Orma herders use the white-grey soils landscapes (oomaar) for dry season grazing because livestock that graze on it do not lose body mass, even during stressful periods (Ibid). Whereas the black soil (kooticha) is suited to wet season grazing. Range scouts (abuuru), young experienced herders are sent by the elders to assess rainfall and forage conditions (Oba, 2012). The Orma identified three types of pasture conditions based on different types of rainfall and livestock grazing. The koono rains that occur in the dry season encourage the growth of browse vegetation, but is inadequate to maintain the growth of grass, and therefore livestock do not migrate to such areas. The second type of pasture is a result of heavy
rainfall, which stimulates high growth of pasture. This is also known as *ooba*, which describes high biomass. The last type is an overgrazed rangeland (*hinbarbadoofte*), avoided by the herders.

The Afar herders of Ethiopia move between grazing landscapes located in different topographies, the uplands (*ale*), the lowlands (*bahari*), and between narrow (*duulul balaa*) and wide (*daaba*) valleys within the Afar rangelands. That rangeland extends between Ethiopia, Eritrea and Djibouli. The floodplain of the Awash River serves as a dry season grazing reserve and the uplands are used for wet season grazing (Oba, 2012). The plains are used for grazing immediately after the rains (when grasses flowered and soils dried). During the wet season, neighbouring clans share water and grazing. The Afar clan leaders (*makabantu*/ *makaban*) play an important role in decision making with regards to clan grazing lands. Clan leaders also set aside grazing lands to cope with drought periods. The conservation of grazing lands came about through agreements amongst the clan leaders.

The Matheniko pastoralists of Karamojong in Uganda use seasonal livestock grazing systems which relies on the assessments made by the traditional range scouts (*ngikereba*) (Oba, 2012). Farmers grazed livestock on black soil (*arro*) landscapes during the dry season and on sandy landscapes (*eketela*) during the wet season.

### 2.2.2 Grazing and livestock management in America

Farmers and peasant communities in Brazil used improved pastures (*Brachiaria* grasses) and tree fodder species (*Leucaena Leucocephala*) which have the economic benefits of increasing animal productivity and diet (Vermeulen and Dinesh, 2016). *Brachiaria* is a plant in the grass family native to Southern America (Rao *et al.*, 2014). Experiences in Brazil have proven that these pastures contribute significantly to farmers' income by extending animal productivity by five to ten times as compared to native savannah vegetation. Breeding practices of *Brachiaria* are being used, producing three commercial cultivars, Mulato, Mulato 2 and Cayman. *Brachiaria* bred cultivars aid in high productivity of livestock, nutritional quality and are tolerant to dry seasons. Deep rooted *Brachiaria* grasses store large amounts of carbon in deeper soil layers (Thornton and Herrero, 2010).
In Jamaica, bauxite soils also known as "red earth" or "Terra Rossa" (Snaith, 1973) are shallow, prone to erosion, droughty and relatively infertile. These soils have been traditionally used for growing pasture species to support ruminant livestock production (Williams et al., 2007). Their production practices incorporate the use of goat manure compost which is applied to crops to supply nutrients and improve soil health and fertility. Crop by products serve as a source of food for livestock and mulch to reduce soil and water losses. Furthermore, farmers also incorporate biochar, a 2,000 year old practice charcoal used as a soil amendment, to increase soil fertility and reduce pollution while providing carbon sequestration (Woolf et al., 2010).

In the Caribbean Islands, farmers use well-adapted livestock breeds raised rustically, using natural and local feeds, traditional housing and breeding resources and methods (González-García et al., 2012). These breeds include Creole cattle or Creole pigs from the French Antilles and Spanish-speaking islands (Cuba, Dominican Republic, and Puerto Rico) and the Creole goat. Using well adapted livestock increases their resilience.

Farmers from the Caribbean islands practice traditional mixed farming system strategies (González-García et al., 2012). They use draught animal power (pairs of adult bovines) for land preparation and transport, in sugarcane producing countries (Cuba, Dominican Republic and Haiti), and recycle solid manure for organic fertilization of crop fields. They also intercrop cassava or maize and beans. Grains and cassava (root) are used for domestic consumption; while crop residues (straws and stems) are used for animal feeding.

2.2.3 Grazing and livestock management in Asia

In Nepal, transhumance pastoralists have developed and used unique institutional practices of using and managing High Altitudes rangeland resources that better suit their context (Aryal et al., 2014).

Transhumance grazing systems - Kalinchowk and Bhairabkunda area, a village council comprising 9-15 members is formed democratically by the local community. Transhumance herders are assigned based on the quality of pasture, and size of herds. Grazing schedules to move (upwards and downwards or during summer/winter) are pre-set; Rules for wood and non-timber forest products harvesting is made; Livestock
taxes are defined. The Chief of the councils or a person or group of households are elected by the council for specified period (usually one year) to act as the “Enforcer”; while the other members of the councils are responsible for supervision, monitoring and reporting

*Shingi Nawa* system of forest and pasture management - In the Khumbu region, *Nawas* are elected democratically by the community on a rotational basis. Norms or rules on timings, areas of pastures, size of herds and sequence of rangeland for grazing and forest use (quantity by types and uses) and other accessory norms/rules required for sustainably managing natural resources are made. Two types *Nawa* exists; *Osho Nawa* and Shingi Nawa (Shingi stands for timber or wood and *Nawa* stands for people who look after forest). *Osho Nawa’s* responsibility is to coordinate the villagers’ agricultural activities and to prevent damage to crops. *Shingi Nawas* are responsible for natural resources management but also look after agriculture and livestock management. The head of local institution - the *Shingi nawa* - enforces the rules and regulation and 3-4 men are especially appointed to monitor rules and regulation and also the assist the chief *Nawa*.

*Gumba* system of forest and pasture management - In Pungmo and Gumba Area of Dolpo, *Chhabu Lama* -the chief Lama of Gumba danda monastery manages the system. Rules are related to ban on hunting and killing of wildlife including birds. Forest management/conservation and harvesting including non-timber forest products, managing and regulating grazing of pasture lands. Local norms related to agriculture system or crop management and laws related to offenses and punishment upon breaches of the customary law. The *Chhabu Lama* is responsible for the enforcement of laws while his assistant Lamas are responsible for the overall implementation, monitoring and reporting of the local rules and regulations. The decision making process is democratic and bottom up and often held at community and household level depending on the types and sensitivity of the cases related to the breaching of customary laws.

Transhumance grazing system - In Humla, Jumla and Mugu, rules and decision making are democratic, transparent and bottom-up and are carried out at the time of village councils before moving to summer pasture. Rules related to grazing cycles, harvesting of forests products and merging of animals and forming herd size; and fixing annual
wages to Noras are made. The *Rokya or Mukhiya* are the main enforcers and Nora are responsible for implementing, monitoring and reporting. Rules and norms are revised at the time of village council while decisions against pasture/pasture offense or conflict between villagers are settled either at community level or at individual household level.

Transhumance Pasture Management – In the Nar and the Phu Valley of Manang, *Ghampa-Ngerpa* and *Gamba-Lhenjing* (local village councils) make the rules. This institution is made up of two types of members, decision makers called "*Ghamba*" and decision implementers known as "*Chow*" in Nar Phu and "*Lenjing*" in Phu. These are clan based institutions and rotational in membership. Each household heads (men only) hold both types of posts at least once in their life time. Rules are mainly related to regulation of forest harvesting, grazing and protection of forest and cultural and religious sites. Grazing taxes are mainly revised on the basis of herd size and their age.

Sat Thari *Mukhiya* System of Forests and Pasture Management - In Baglung, the chief of the Village Council is the *Mukhiya*. Rules are mainly related to the regulation of forest harvesting, grazing and protection of forest from encroachment and fire; Membership eligibility is based on residence (villagers only), age (15-60 years) and, open to married men only. The overall responsibility of enforcing the laws lies on the *Mukhiyas*. However, each other members are also equally responsible for the implementation, supervision and monitoring of activities. Decisions are democratic in nature and are made at the time of annual village council’s meeting.

The *Kipat or Subba* system of forest and pasture management system is employed in Far Eastern region of Nepal (Aryal *et al.*, 2014). Under this system, *Amali Subba or Pagari Subba* (the head of *amal*), manage set rules for the management of land (agriculture), forests, pasture, and biodiversity, as well as rules for wild life poaching and hunting; forest harvesting. They also set fees for use of forests/pasture and forest products for non-kipatiyas. The decision making process is democratic and bottom up. Issues are presented orally before community members and witnesses. Experienced and elderly persons from the communities are invited as a symbol of fairness and justice. The ‘*Amal*’ (local court) is an institution that provides support and implements traditional practices and customary laws (Khatri, 2008).
The Bhotiyas pastoralists of the Kumaon Himalaya (central India), have for centuries used a farming and livestock management system different and unique from the rest of Kumaon region. For centuries, Bhotiya have practiced migration and vertical transhumance for grazing their livestock (Farooquee and Rao, 2000). Vertical transhumance, is an important animal husbandry practice used by pastoralists living near mountainous terrains that helps provide livestock with a continuous source of quality graze throughout the year (Makarewicz et al., 2017). Professional shepherds take sheeps and goats of the Bhotiyas down to the lowlands and foothills during the cold period, between May and September. Due to legal regulations the shepherds are allowed to use one pasture for 10-15 days only (Nüsser and Gerwin, 2008). Nowadays, cattle are the preferred species for agriculture in the middle sections of the High Himalayan valleys within the vicinity of the former trade depots.

Bhotiyas pastoralists also allow their livestock to graze openly in the nearby forest and in the alpine meadows during the summer season. The alpine meadows of the western Himalaya are known for their high floral diversity (Farooquee and Rao, 2000). Access to grazing resources is uniform to all, and there are no specific tracts of land for any family. Due to the declining grazing resources in the Himalayan region, customary institutions have provided the framework for sustainable use of rangeland resources by pastoralist communities (Miller, 1998; Banjade and Paudel, 2008; Pandey et al., 2017). Institutions are one of the crucial keys to sound natural resource management (Dong et al., 2009).

Similarly, transhumance sheep farming is practiced in the Northern high altitudinal regions of Nepal. The chief herders move their herd upward in the early summers for utilizing the alpine pastures and downward in late autumn or in early winter to protect their herds from cold winter weather of the high altitude (Barsila et al., 2014). Additionally, cross breeding of Yak (indigenous breed) is avoided, thus help support higher performance of hybrid vigour and improved adaptation.
In China, the grasslands are mainly distributed in the Inner Mongolia Plateau, the Loess Plateau and the Qinghai-Tibetan Plateau (Liu, 2017). The Inner Mongolian Plateau grasslands are the most commonly used for grazing. Before, privatization of grasslands and the decentralization of herders, inner Mongolian pastoralists practiced a nomadic strategy, concentrated on seasonal migrations that allowed grasslands recovery after use (Conte, 2015). The traditional ecological knowledge of Mongolian folks is the basis for deciding, when and where to move the herd based on the preferred livestock plant species and seasonal dietary as well as water needs. This nomadic livestock management system significantly contributes to the sustainable management of the Inner Mongolian grazing land. It promotes the efficient utilization of grassland resources and the distribution of herds to available pastures (Conte, 2015).

The Tibetan steppe of Asia, experienced substantial livestock losses. This has persuaded the authorities to restructure the transhumant pastoralism (Sheehy et al., 2006). However, currently, summer grazing lands are being privatised and fenced, except in the Tibetan Autonomous Region where rangelands are allocated to groups of herders rather than to households.

In the Dindori and Chhindwara districts, Madhya Pradesh of India, two types of grazing systems are used, private and common grazing land. In common grazing land, animals are directed by rules and regulations for access to the different pasture categories. These grazing areas are logistically partitioned and are distant from intensive agricultural fields to avoid any conflict arising from undesirable trespassing and grazing of crops. Access to the different pasture and rangeland categories are dictated by the limited availability of water at the peak of the dry season. Forage-banks in private grazing lands and village forest are reserved for weak and sick animals for use during periods of forage scarcity (Singh and Sureja, 2007). Moreover, for the sustainable use of natural resources, they stratify their livestock and assign grazing land accordingly. For instance, calves (Bachhada) of both sexes (cow) younger than 6 months are kept in normal cattle shed with assured rearing and are regularly supplemented with forage, in addition, dry cows (Bishuki Gai) and adult males (Bail and Bachhada) move to more distant pastures and cover wide range
of grazing. Livestock owners have reserved lands, specifically for regenerating the vegetation and used as pasture land, while the common pasture land is governed and managed by the villages and accessibility for the outside boundary of the villages is restricted.

Pastoralists of the Nariyan village, Iran, manage their flocks by seasonally uniting them to larger herd for increased yield in dairy production. Pastoralists use several methods to hold their herds together. The animals are trained to listen and react to particular words and sounds. These sounds guide and direct them to the water or grazing ground, or they may forbid movements. A bell is usually tied to a buck (*kal*), because the pastoralists believe that the *kal* is intelligent and reacts very quickly in case of danger, alerting the shepherd’s dog to combat the danger. The sound of the *kal’s* bell indicates the speed of the herd’s movement to all of the animals and prevents the shepherd from falling asleep (Ghorbani et al., 2013). In terms of grazing land management, the pastoralists divide the rangelands based on their readiness of rangeland fodder plants and topographic conditions. The rangelands are divided into *Nesar* (behind the sun) and *Baraftab* (in front of the sun). Pastoralists closely monitor the stages of plant growth, to avoid releasing flocks too early which will degrade the vegetation cover (Ghorbani et al., 2013). In addition, certain rangelands close to the village, known as the *Harim or Alaf Chin* (forage and cutting), are chosen by the Islamic Village Council for grazing a limited number of larger animals, such as cows, and for cutting grass to be stored for winter feed. In the high and middle rangelands, an annual rotation system take place to ensure equal access grazing lands (*Ibid*).

2.2.4 Grazing and livestock management in Oceania
2.3 Topic 1.3. Soil and Water Management (including cross slope barriers)

2.3.1 Soil and water management in Africa

Soil conservation practices have been widely adopted in Tougou, northern Burkina Faso in the past few decades (Barbier et al., 2009). Adopted soil conservation methods include a process of corralling, where farmers enclose their animals on their fields during the dry season in order to ensure manure availability for soil fertility.

Furthermore, local farmers in the Sahel have been known to conserve C in soils through the use of zero tilling practices in cultivation, mulching and other soil management techniques (Schafer et al., 1989; Osunade, 1994). Natural mulches moderate soil temperatures and extremes, suppress diseases and harmful pests, and conserve soil moisture. Before the advent of chemical fertilizers, local farmers largely depended on organic farming, which also is capable of reducing GHG emissions (Nyong et al., 2007). Local populations across Africa, through their indigenous knowledge systems, have developed and implemented extensive mitigation and adaptation strategies that have enabled them reduce their vulnerability to climate variability and change.

In the Atacora and Save zones of Benin, farmers believe that increased climatic variability (less and more irregular rainfall), runoff, erosion, and overexploitation of farmlands have caused land degradation. Soil fertility status is assessed using dicotyledonous weeds, soil texture and colour, and soil fauna (earthworms casting activity) (Saïdou, 2006). Farmers have adapted their cropping systems to the local environment by developing traditional and new strategies and activities that could contribute to maintain or enhance crop productivity. These strategies include animal manure, inorganic fertilizer, crop rotation, and a five-year fallow, extensive cropping systems with cassava or egusi melon, and migration. Significantly, in the North-Western part of Benin, the appearance of certain weeds on the land indicates to farmers whether the soil is fertile or infertile (Saïdou, 2006). Women on their individual or collective farms in the Atokora region of Benin often grow grain legumes, except groundnut in other to ensure soil fertility. Usually other crops are grown after the legumes have been harvested (ibid).
Strategies to maintain soil fertility may not only involve biophysical interventions. If the productivity of the land cannot be sufficiently increased, pressure can be put off the land by migration. Migration is a strategy used by the younger generation. The older generation generally decides to stay, and applies household waste, animal manure, or a combination of inorganic fertilizer and animal manure or household waste a way of improving soil productivity (Saidou, 2006).

In the Ouémé Valley of Benin, the finger ponds previously dug in flood-plains to trap migrating fish during the flooding, have become predilection areas for agriculture. Thus, from simple holes, the finger ponds became agro-fishing techniques whose pits retained their traditional use of fish ponds, but the dykes henceforth more broad and forming high strip lands are used for dry-season cropping (Kpadonou et al., 2012). Cropping dykes in the Ouémé Valley of Benin are the strip of land that surrounds the agro-finger ponds. It is the earlier emergence of soil collected to create the finger pond. The dykes have covered with mulching for holding water and reducing soil moisture loss (Kpadonou et al., 2012).

Farmers in the northern part of Ghana generally cultivate large tracts of land as a form of insurance in case there is crop failure (Yaro, 2010). Dry season gardening and compound farming has become very important, especially along the river beds and around homes of farmers usually using hand-dug wells. In the case of the community from the Sudan savannah, some of the community members commute to the banks of the White Volta, which is about ten miles from the community. They cultivate vegetables like onions, tomatoes, okra, and aleefu, which give them a good source of income (ibid).

### 2.3.2 Soil and water management in America

Farmers in the southern area of St Elizabeth, one of Jamaica’s largest parish, produces large quantities of Guinea grass (*Panicum maximum*) despite being the driest parish of the island (Simpson, 2010). The adaptability of Guinea grass, a perennial tufted grass, to tropical climate drought-like conditions and a variety of soil types makes it suitable fodder for local livestock. The grass is cultivated as a mulch crop, and this is either transported to the planting area or used in situ after cutting. Crop plants are introduced directly into plant holes which are dug through the mulch material. There is limited irrigation during crop growth and the mulch helps to conserve soil water
which is obtained from rainfall. These cultural practices were developed as a result of the dry conditions and produce economically acceptable yields in the area.

In Mexico, farmers and agricultural organisations, apply silvopastoral practices. This is the integration of trees with forage and livestock production (Pagiola et al., 2004). Silvopastoral practices are used to overcome cattle production systems, providing deep root systems and dense perennial vegetation. Plantation of trees and shrubs with high densities in pastures provide shade and diet supplements as well as soil protection from erosion and packing. Increasing plant diversity helped in the maintenance or improvement of pasture productivity through expanding nutrient recycling and production diversification. Silvopastoral practices fixed large amounts of carbon in the soil and tree biomass.

Communities near the Xochimilco-Chalco Lake in the Mexico City used chinampas are raised platforms (floating gardens), which are narrow enough to supply water for growing crops in shallow-land zones (Altieri and Koohafkan, 2008). It is a Mesoamerican agriculture which used small, rectangular areas of fertile arable land to grow crops on the shallow lake beds. Chinampas are very useful during the dry season, when lake levels fall below the rooting zone. The narrow canals allow the chinampero to irrigate from their canoes. Chinampas reduced soil erosion and increase water filtration towards the roots, reducing farmers’ vulnerability to erratic rainfall. The soil platforms are continuously enriched with organic matter that is produced together with aquatic plants and sediments. In chinampas the major source of organic matter comes from the water hyacinth (*Fichornia crassipes*), which is an aquatic plant native to South America. This plant is used as fodder/forage/animal feed, mulch as well for the removal of nutrients and toxic chemicals in water (Holm, 1997).

The Otomi ethnic group, in Mezquital Valley (Mexico), used Maguey (large agaves of Mexico and the southern US) to manage soil during the establishment of terraces to reduce soil erosion (Altieri and Toledo, 2005). Of the approximately 200 species in the Agave genus, several taxa have long benefited indigenous groups throughout the U.S. Southwest, Mexico, and Central America as food, beverages, sweetener, bioenergy, fibres for ropes and fabrics (Stewart, 2015).

Communities near Lake Titicaca, on the border between Peru and Bolivia, use an ancestral technique known as the *waru-waru* (high beds), which facilitate draining,
prevent flooding, and help to aerate the roots (Aguilar and Jacobsen, 2003). During dry periods, the *waru*–*waru* store enough moisture during dry periods (Saylor et al., 2017). This technique reduces the impact of extreme weather as it stores heat and maintain soil fertility, helping farmers adapt their agricultural production to current and future impacts of climate change.

The agro-ecological zone on the Peruvian Altiplano is large and complex, containing an ample variability of agricultural production determined by specific physical factors (Aguilar and Jacobsen, 2003). The relief of the soil surface, soil type, and its hydric characteristics, are the principal factors determining the effects of exposure to climatic factors. The temperature varies in the different physiographic zones (upper part of hill, slope, hill foot, crest, plain, and lakeshore). The top of the hill or mountain is the coldest part, posing few possibilities for agricultural production. In each physiographic zones, communities grow the most appropriate plant cultivars. The slope areas are favourable for cultivation of a range of species, including potatoes and other Andean tubers (*oca, mashua* and *ulluco*), seed crops (barley, wheat, rye, and field beans), and *quinoa* cultivars with low frost tolerance (white grains). In the highest situated agro-ecological zone of the Puna, the slope is the only cultivable area, with the only crop options being bitter potato, *cañiwa* (chenopodium pallidicaule Aellen), and *quinoa kcoitos*.

Cultural adaptations that farmers have developed in the Andes include (Altieri, 1996):

- domestication of a diversity of plants and animals and maintenance of a wide genetic resource base;
- establishment of diverse production zones along altitudinal and vertical gradients;
- development of a series of traditional technologies and land-use practices to deal with altitude, slope, extreme climates, etc;
- different levels and types of social control over production zones, including sectorial fallows.

In the Lake Pátzcuaro river basin in the state of Michoacán, Mexico, the Tarrasco indigenous people cultivate corn using a range of land management practices based on agricultural and climatic indicators, as well as local festivals. The knowledge includes a system for classifying and zoning agricultural land use based on the biological characteristics of different corn varieties (Chillon, 2008).
To manage native and wild agrobiodiversity, throughout the Andes, there is a long tradition of agricultural practices that conserve the natural diversity of crops such as potato, quinoa grain, squash and fruits. Traditional mountain communities possess a rich knowledge of the genetic characteristics and varieties of each native crop and its wild relatives. Using this knowledge, the communities apply selective breeding methods to increase the resilience of cultivated crops to variable environmental conditions brought about by global climate change (ibid).

2.3.3 Soil and water management in Asia
Conservation of soil and water resources is the most important feature of sustainable development. Soil erosion may cause severe loss of topsoil where organic matter and vital nutrients needed by crop. Loss of organic matter and soil nutrients harms farmland’s suitability for farming and reduces its ability to retain water. Indigenous peoples with a historical continuity of resource use practices often possess a broad knowledge base of the behaviour of complex ecological systems in their own localities.

Traditional farmers in the central Himalayan use various methods for soil and moisture conservation (Negi et al., 2003). In summer, farmers collect pine leaves and spread them over their paddy rice fields and burn them. The inflammable pine needles burn rapidly and consume the weeds and their seeds/ root stock at the soil surface. Consequently, soil fertility is improved. Furthermore, farmers also gather and weeds and minor crops allow them to dry and they put them back to the crop fields because they believe that ash enhances soil fertility while, burning controls weed infestation.

Himalayan farmers use flood water, because it carries organic matter and humus along with it and deposits fine silts that increase soil fertility. Furthermore, they practice in-situ maturing in the crop field. The practice involves keeping livestock (cattle) overnight in the field for days after the Kharif crop harvest. When the dung and urine deposition on the fields is considered adequate the livestock is moved to another fields. Additionally, to minimize water needed for germination, these farmers use wet soils
mixed with seeds of rye (*Brassica nigra*) placed inside the holes left between the stones of terrace risers (Negi *et al.*, 2003).

Irrigation in the Himalayan region is done through mud line canals (*kuhl* or *gul*), carved out of the hill slope along the gradient of gravity. Farmers, irrigate crops based on traditional knowledge. For instance in paddy fields, irrigation is done 7-8 times throughout the growing period when the normal water supply is available.

The Himalayan farmers also paved different ploughing method that conserve soil moisture. After the winter rains, crop fields are ploughed and compressed levelling is done using a heavy wooden plate. This practice conserves soil moisture in the deeper layers of the soil to obtain good seed germination. Fields are ploughed soon after crop harvest at the end of the rainy season. Additionally, in autumn when the fields are under fallow farmers’ saturate them with water to avoid competition for water during the seedbed preparation. Seed sowing is also done in a circular way to raise paddy nursery, this technique is known in the region for conserving water compared to broadcasting sowing and line sowing (Negi *et al.*, 2013).

Many regions South East of Asia, parts of Indonesia, China (Longxian village of Zhejiang province) and Philippines have transformed wet and humid lands into highly productive rice fields (Sharma *et al.*, 2014). Rice is commonly cultivated engrossed in water and sometimes alongside edible fish. Farmers in these regions believe that cultivating rice next to edible fish keeps weeds that are potentially harmful to rice under control and simultaneously fertilizes the land in a natural way. Additionally, green manure, farm yard manure, in-situ such as by keeping sheep and goats, mulching, use of nitrogen fixing plants, crop rotation, fallowing, terrace risers slicing, trapping flood water for fertigation, burning of trash use of forest and black soils, burying dead animals and mobile toilets are recognized as indigenous soil fertility management practices in Nepal (*Ibid*).
In the Gwallek–Keda (Baitadi district, Nepal), farmers plant legume crops in paddy fields. They also intercrop soybean with maize and apply farmyard manure to improve soil fertility (Atreya et al., 2018).

In central Iran toward the east and southeast of Iran, underground drainage tunnels (qanat) are used. Qanats are built with a slight slope to guarantee a slow but constant flow of water that prevents erosion of the tunnel walls. Being about 1½ meter high and ¾ meter wide, qanats are rather narrow, but they can reach depths of 30 meters (the record seems to be 60) and can cover distances of many kilometres. A qanat system consists of an underground part and a part above ground surface. The underground part is divided into the water production section and the water transport section. In the water production section, water is collected either from a natural source or through infiltration of groundwater (Clarke, 1990).

2.3.4 Soil and water management in Oceania

Climate change directly affects the poor who are most dependent on the ecosystem services for their livelihood. Farmers, herders and other poor households face many practical challenges such as severe drought and flooding, declining agricultural productivity and unsustainable production practice. The traditional knowledge base regarding, skills in and capacity for managing water for different uses have a long history among the communities of Asia.

In West Sumatra Indonesia, water resources is controlled and regulated by custom. The traditional irrigation systems are managed by ninik mamak (indigenous elders), which are directly appointed by kapalo banda (the head master of irrigation) to regulate water sharing during the night (David and Ploeger, 2014). Farmers have to keep to the prescribed schedule in order to water their field. In addition, the land has be watered at night between 6 pm and 6 am and there should be no runoff from it. There are penalties for breaking the rules. Planting time is in accordance with the local understanding of the micro climate fluctuations (David and Ploeger, 2014). Knowledge of the seasonal changes plays a key role in temporal towards sustainable resource use such as rotation of traditional grazing by herders in West Sumatra, Indonesia.
To prevent coastal erosion in Ace, Indonesia the coastal forest is managed by the traditional fishermen organisation, several rows of different species of trees, bushes, smaller vegetation are planted along the shore to prevent and mitigate impact from high waves and strong winds (Hawasaki et al., 2014).

Farmers in East Nusa Tenggara (Indonesia), have several practices to improve soil fertility and prevent erosion, such as slash and burn cultivation on rotation basis, integration of trees into field, as well as building contour barriers from dry branches, shrubs, and bamboo (Langill and Landon, 1998).

Farmers in Nepal use traditional irrigation systems and have institutions that manage water distribution. These institutions regulate water use, based on socio-economic circumstances and other stresses in the area (MOSTE [n.d]). Farmers use Sancho (a devise cut from tree trunk), in irrigation canals, to distribute water to smaller canal that serve farming plots. Farmers also use bushes, wood, mud and stones as Sancho (MOSTE [n.d]). These traditional methods can be seen in Panchakanya Irrigation System in Chitwan District and Sorah-Chhatis Mauja Irrigation System in Rupandeh District of Nepal. Local people of Kathmandu, Patan and Bhaktapur use Dhunge dharas and Paani Pandheros that tap natural springs (MOSTE [n.d]). Dhunge Dhara is a traditional stone water tap that originate from Nepal.

In the Chure region, Nepal farmers plant amriso (bouquet grass) and babiyo (Eulaliopis sp.), species ton stabilize soil properties. Traditional communities in Nepal also plant bamboo species to conserve soil and control runoff in gullies and shady (MOSTE [n.d]).

2.4 **TOPIC 1.4. WATER HARVESTING AND STORAGE PRACTICES**

Rainwater harvesting (RWH) is a subdivision of water harvesting (WH) but, the two terms are used interchangeably (Mwenge Kahinda et al., 2011). The major categories of RWH when classified according to the use of the harvested water are: non-agricultural (residential, industrial and commercial) and agricultural RWH. While the former category encompasses harvest water from rooftops, terraces, courtyards and other impervious building surfaces for on-site use; the latter category encompasses subsistence, small-scale and commercial agriculture. The line is quite blurred, considering that some residential RWH systems, such as Polyvinyl chloride tanks, are
used to water small vegetable gardens. RWH for agricultural use is further discretised according to the type of catchment surface used into in-situ RWH (iRWH) and ex-situ RWH (xRWH) and each has an array of techniques.

Ancient and traditional RWH technologies were either developed or started in response to the past climate change events, which included annual and multi-decadal fluctuation in precipitation patterns (Lucero et al. 2011; Pandey et al. 2003). Their subsequent decline has been mostly documented by historians and anthropologists (D’Souza, 2006). The complex array of factors responsible for either the decay, the disruption or the disappearance of traditional systems ranges from imperialism, to incomplete understanding of local ecology, to disruptive social organisation introduced by colonialism. Although over the past four decades RWH is pioneered across the globe, RWH adoption rates are still low. Subsistence farmers are reluctant to invest time and money in setting up RWH structures, as they often have no security of land ownership and/or limited access to local markets where they could sell surpluses of food or cash crops (Drechsel et al., 2005). It is very difficult to distinguish between indigenous, indigenised and contemporary water harvesting systems. Indigenous system are those that were developed locally, indigenised systems, are hybrid solutions incorporating external influences, and finally, contemporary practices are those introduced more recently by scientists or development agencies (Denison and Wotshela, 2012).

Akpinar Ferrand and Cecunjanin (2014) identified fifteen major types of ancient and traditional RWH categories (Table 2.1) that were alike in practice and function despite the different climatic regions, in which they were found, or the cultures that practiced them.

Table 2.1. Fifteen commonly practiced ancient and traditional RWH strategies.

<table>
<thead>
<tr>
<th>RWH strategy</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>(1) Pitting:</td>
<td>Pits are dug and planted with cultivars on flat or sloping surfaces. Pitting conserves soil moisture and increase ground water recharge. Pitting will reduce velocity of precipitation-engendered runoff if built along a contour.</td>
</tr>
<tr>
<td>(2) Contouring (stone/soil bunds, hedgerows, and vegetation barriers):</td>
<td>Contouring involves stone or earthen banks along a contour in a cultivated hill-slope. Hedgerows typically involve vegetation planted along a contour or cross-slope barriers of grasses and herbs. Contouring helps retain soil moisture, reduce soil erosion, and shorten slope length.</td>
</tr>
</tbody>
</table>
(3) Terracing: Bunds in association with a trench along a contour on a sloping surface. Terracing helps reduce velocity of runoff during precipitation events, conserve soil moisture, and reduce erosion.

(4) Micro-basins: Different shapes of small basins, surrounded by stone or earth bunds to infiltrate precipitation related runoff.

(5) Pit courtyards: Pit courtyards act as an impluvium to capture rainwater, surrounded by walls and impervious surfaces.

(6) In situ RWH: Designed for increasing rainfall infiltration and reducing soil evaporation through practices such as ridging, mulching, broad bed and furrowing, hoeing, and conservation tillage.

(7) Rooftop RWH: From rooftops, water is collected and stored in storage tanks built in courtyards of houses.

(8) Traditional open ponds: Precipitation and runoff is collected in open ponds through a catchment system. Ponds may or may not have lining. Absence of lining may lead to seepage.

(9) Cisterns: Runoff collected and stored in underground storage reservoirs. Ancient cisterns may range from natural or excavated depressions in solid rock to lined structures.

(10) Micro-dams: Stored and regulated flow of rainwater runoff for infiltration behind stone/earthen banks in a landscape with gradient. Some micro-dam surfaces are planted after drainage to utilize silt deposition and higher soil moisture.

(11) Shallow wells: Shallow wells dug in low depressions or ponds to collect surface runoff after percolation to extract water during the dry season.

(12) Underground well systems: A proximate horizontal channel network or gallery excavated into an alluvial fan aquifer at the base of a mountain or foothill, recharged by precipitation.

(13) Runoff diversion and spate irrigation: Diversion and spread of seasonal floods to agricultural plots from discrete rainfall events. These kinds of systems can be connected to terraces, reservoir systems, and dams of different sizes.

(14) Dams: Stored and regulated flow of rainwater, runoff, and ephemeral streams behind large storage systems that are constructed around foots of hill slopes.

(15) Large reservoirs/lakes: Precipitation and runoff collection in large-scale human-made basins

Furthermore, utilising the common RWH categories identified in (Table 2.1), Akpınar Ferrand and Cecunjanin (2014) identified and listed a good number of ancient and traditional societies that practiced them (Table 2.2).

Table 2.2. Ancient and traditional RWH practices from semi-tropics (dry-wet), semi-arid, Mediterranean, and arid regions.

<table>
<thead>
<tr>
<th>RWH techniques</th>
<th>Semi-tropics (S and 10 and 23.5°)</th>
<th>Semi-arid Mediterranean (20–45°)</th>
<th>Arid (20–45°)</th>
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<tbody>
<tr>
<td>RWH techniques</td>
<td>Semi-tropics (5 and 10 and 23.5°)</td>
<td>Semi-arid Mediterranean (20–45°)</td>
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<tr>
<td>(2) Contouring (e.g. stone/soil bunds, hedgerows, and vegetation barriers)</td>
<td>1. Contour farming systems, East and West Africa. 2. Southeast Asia.</td>
<td>1. Metlapingli or bordos contour terracing in Pre-Columbian and Colonial Mexico. 2. East and South Africa. 3. Traditional use of contour bunds, NE and NW Iran. 4. Ancient and traditional use of contouring, Central Asia. 5. Vegetable fiber contours, China.</td>
<td>1. Ancient and traditional use of contouring, American SW. 2. Ancient use of contouring, Negev Desert, Israel. 3. Tera systems, SE Sudan. 4. Ancient and traditional use of contouring, Yemen. 5. S Jillas and Kusakba systems, Baluchistan.</td>
</tr>
<tr>
<td>(6) In situ RWH (e.g. ridging, mulching, hoeing, broad bed and furrowing, and conservation tillage).</td>
<td>1. Ancient use of contour strips and bunds, N Africa. 2. Ancient and traditional use of mulching and terracing, Africa. 3. Historic use of ash and cinder mulching, Lanzarote, Canary Islands. 4. Traditional in situ RWH practices, Sub-Saharan Africa. 5. Ancient and traditional in situ RWH practices, Yemen.</td>
<td>1. Ancient and traditional American SW, waffle and grid gardens. 2. Micro-basins (e.g. half-moons), Canary Islands. 3. Micro-basins, West Africa. 4. Karm rock-wall gardens, Egypt.</td>
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<tr>
<td>(7) Rooftop RWH</td>
<td>1. Tankas, India. 2. Motkas and Kalshi rooftop RWH, Bangladesh. 3. Traditional rooftop RWH practices in Kenya, Indonesia, Thailand, Vietnam, and Southern China.</td>
<td>1. Colonial rooftop RWH practices, Mexico. 2. Traditional use of rooftop RWH, NE Brazil. 3. Antiquty rooftop catchment systems, Mediterranean. 4. PVC and Djabar tanks, Sub-Saharan Africa. 5. Traditional jar/clay pot rooftop RWH, Gansu, China.</td>
<td>1. Traditional rooftop RWH practices, Canary Islands. 2. Traditional rooftop RWH, North Africa (Soufirs/Tkhabit, Algeria)</td>
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<tr>
<td>RWH techniques</td>
<td>Semi-tropics (5 and 10 and 23.5°)</td>
<td>Semi-arid Mediterranean (20–45°)</td>
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<td>(9) Cisterns</td>
<td>1. Pozos cuadrados, walk-in wells, Tehuacan Valley, Mexico.</td>
<td>4. Ancient and traditional use of cisterns, North and Sub-Saharan Africa.</td>
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<td>2. Cisterns of semi-arid NE Brazil.</td>
<td>5. Ancient cistern use, Arabian Peninsula.</td>
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<td>3. Phonecian, Carthaginian, Hellenistic, Ancient Roman, and Byzantine cisterns of Mediterranean Antiquity.</td>
<td>6. Step-wells of Western India.</td>
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<td>4. Hittite, Urartu, and Ottoman cisterns, Turkey.</td>
<td>7. Kunds and Tankas of Western India.</td>
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<td>5. Abanbar cisterns, Iran.</td>
<td>8. Shuijiao cisterns, China.</td>
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<td>2. Munundum high earth banks, Brazil.</td>
<td>2. Kuis/Beris deep pits dug near tanks, to utilize seepage, Western Rajasthan, India.</td>
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<td>4. Bandasar system, NE Iran.</td>
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<td>5. Ahar systems, Bihar, India.</td>
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<td>6. Johad and Rapats, Rajasthan, India.</td>
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<td>7. Liman high banks and Khaki system, Central Asia.</td>
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<td>8. Ancient China</td>
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<td>2. Pit-like shallow wells dug into Laghi lakes, Italy.</td>
<td>2. Trinchera rock curtains, Northern Mexico.</td>
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<td>3. Ancient Egypt.</td>
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<td>4. Meskat and manka systems, Tunisia.</td>
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<td>5. Khadins (dhora), Western Rajasthan, India.</td>
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<td>6. Kuis/Beris deep pits dug near tanks, to utilize seepage, Western Rajasthan, India.</td>
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<td>(12) Underground wells.</td>
<td>1. Sarangams, SW India.</td>
<td>1. Naqqa Puquios shallow underground wells, Peru and Northern Chile.</td>
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<td>2. Foggara, North Africa</td>
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<td>3. Aflaj/Falaj, Arabian Peninsula.</td>
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<td>5. Paar systems, Western Rajasthan, India.</td>
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<td>6. Karez, Xinjiang, China.</td>
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<tr>
<td>(13) Runoff diversion and spate irrigation.</td>
<td>1. Canal and pond runoff diversion systems, ancient Maya, Central America.</td>
<td>1. Ancient and traditional systems, American SW.</td>
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<td>2. Inundation channels in connection to tanks/ponds/lakes, Bengal, India.</td>
<td>2. Pre-Columbian runoff diversion systems, Mexico.</td>
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<td>3. Katas/Mundas/Bandhas irrigation system Madhya Pradesh, India.</td>
<td>3. Moche IV and Inca Empire, Peru.</td>
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<td>2. Esseed. dams, Algeria.</td>
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<td>3. Ancient dam in Jawa, Jordan.</td>
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<td>4. Marib Dam, Yemen.</td>
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<td>(15) Large reservoirs</td>
<td>1. Large-scale reservoirs of ancient Maya.</td>
<td>1. Large-scale reservoirs, ancient Yemen.</td>
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<td>2. Barays of Angkor Wat, Cambodia.</td>
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<td>3. Sagar lakes in India.</td>
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<td>4. Large tanks, Burma.</td>
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<tr>
<td>RWH techniques</td>
<td>Semi-tropics (5 and 10 and 23.5°)</td>
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There is a difference between a conventional dam and a RWH storage system. RWH storage dams get their water from undefined drainage networks; the water collected is used for supplemental irrigation and their storage capacity does not exceed 0.5 Mm$^3$ (Mwenge Kahinda et al., 2007).

2.4.1 Water harvesting in Africa

In many parts of Burkina Faso (Yatenga region) and Mali (Dogon Plateau region), there has been a revival of the old water harvesting system known as zai. The zai are pits that farmers dig in rock-hard barren land, into which water otherwise could not penetrate (Altieri and Koohafkan, 2008). Farmers have become increasingly interested in the zai as they observe that the pits efficiently collect and concentrate runoff water and function with small quantities of manure and compost. The practice of zai allows farmers to expand their resource base and to increase household security.

In northern Burkina Faso, Sahelian community, farmers have adopted several soil conservation practices, such as stone bounds, the zai and composting and manuring techniques. These local methods have helped them reduce their crop and livestock vulnerability to climate variability. According to farmers, most of the new techniques have been adopted because of growing land scarcity and new market opportunities, rather than because of climate variability.

Interestingly, farmers who were a part of the development of the zai method from the onset have made it their mission to promote its spread and further improvement. The Zai planting method has been employed by traditional farmers across Burkina Faso and other countries through what is called the Zai model (Ouedraogo and Sawadogo, 2001). There are three different styles or models in training farmers in the use of the zai method: The zai market day-model where farmers come from different places to see and learn the zai method, the material and tools used. Secondly, through the zai school-model, this is where farmers dedicate themselves to teach groups of farmers in the making and use of the zai strategy. And, the zai teacher-student model, this is where an experienced farmer go from village to village and teach individual farmers to
make zai. The students are then required to transfer this knowledge (Ouedraogo and Sawadogo, 2001).

2.4.2 Water harvesting in America

Communities in Mexico, Bolivia and Peru, use rainwater harvesting practices together with traditional agro-ecological methods, *q’otañas* (form of rainwater harvesting using clay layers of soil), *q’ochas* (superficial depression that stores water), and *waru-warus* (raised fields that have canals surrounded by ditches that are filled with water) (Zavala et al., 2018). These practices improves local supply of water, as it enhances soil infiltration, as well as enhances biomass production as it is structured to trap sediments (Wilk and Wittgren, 2009).

The Otomi community of Mexico builds *bordos* (small tank like rainwater harvesting and storage structure) for trapping rainwater on hillsides. *Bordos* are placed along contours together with stones and maguey plants (*Asparagaceae*) to store rainwater for irrigation and reduce erosion (Altieri et al., 2005).

On hills, ditches and trenches are used to store water. On gradual inclines, borders, terraces, earth dikes, and watering holes are built, making it easier to irrigate crops as well as water cattle (Altieri and Koohafkan, 2008). Terraces were structured in such a way that they absorbed heat during the day time and released it during the night, this creates warmer micro-climate that preserve crops from frosts, extending the growing season of crops and crop diversification (Clements et al., 2011).

In Mexico, the *Cajete* Terrace agro-ecosystems have been in place for 3,000 years in hillside regions in Tlaxca (de la Torre et al., 2010). In these rainfed, corn-bean-squash agro-ecosystems, food is grown on steep, erosion-prone slopes. Rainfall is concentrated between May and September and often occurs in sudden downpours. Sloping terraces feed excess water into *cajetes* (underground tanks) and slowly percolates into the surrounding soil after the rain has ended. Eroded soil is also trapped into the *cajetes*, preventing soil loss down the slopes. Nutrients rich soil inside the *cajetes* is later gathered and distributed into the field.

The terraces throughout the Andean slopes, and the *waru–waru* (raised fields) and *qochas* (excavated pits) in the Altiplano are examples of successful adaptation to
difficult environments by indigenous farmers (Altieri, 1996). These systems are productive, sustainable, ecologically sound, and tuned to the social, economic, and cultural features of the Andean heterogeneous landscape.

The Aymaran indigenous people of Bolivia have been coping with droughts through the construction of small dams called “qhuthañas” (de la Torre et al., 2010). These dams collect and store from 50 to 10,000 cubic meters of rainwater. Predictions on the intensity of the droughts are based on the knowledge and observations of the “yatiris” (wise men or advisers).

2.4.3 Water harvesting in Asia

2.4.4 Water harvesting in Oceania
In Timor-Leste, local communities dig small holes (be’e matan/posu”) next to the river bed to collect clean water. The water seeps through the sand and wells up through the soil. Many communities in rural areas still continue to use this practice to access clean water during wet and dry seasons in their efforts to adapt to climate change (Pinto, 2014).

2.5 TOPIC 1.5. AGROFORESTRY MANAGEMENT AS A COPING STRATEGY TO WATER SCARCITY.
Several criteria can be used to classify and group agroforestry systems (and practices). The most commonly used ones are the system’s structure (composition and arrangement of components), its function, its socio-economic scale and level of management, and its ecological spread (Nair, 1985). Structurally, the system can be grouped as agrisilviculture (crops - including tree/shrub crops - and trees), silvopastoral (pasture/animals + trees), and agrosilvopastoral (crops + pasture/animals + trees).

2.5.1 Agroforestry management in Africa
In Africa, farmers have conserved and incorporated trees in their landscapes. Traditionally farmers grow crops under scattered trees of different species. Some of
the agroforestry practices that are being implemented by the rural communities in Africa include: rotational woodlots (Kalabe et al., 2010; Cook and Grut, 1989), improved fallows (Cook and Grut, 1989), indigenous fruit trees in the parkland system (Boffa, 2000; Chitakira and Torquebiau, 2010; Cook and Grout, 1989; and Kalabe et al., 2010; Mbow et al., 2014), taungya systems (DAFF, 2017; and Steppler and Nair, 1987), homegardens (Cook and Grut, 1989), tree crops and shade trees (Cook and Grut, 1989), savannah grazing (Cook and Grut, 1989), silvopastrol systems (Msuya and Kideghesho, 2012), and live fence-posts and windbreaks (Steppler and Nair, 1987).

Woodlots have been encouraged in densely populated areas in Africa where natural fuel wood supplies have nearly disappeared. They are one of the agroforestry options with the potential to arrest deforestation and shortage of wood fuel energy in Southern Africa (Kalabe et al., 2010). Woodlots are tree stands planted on farms, communal land or degraded lands to provide products and services, as they promote biodiversity conservation and reduce deforestation.

In Zambia the rural households intentionally preserve fruit trees on their fields when practicing parkland systems in agricultural land (Kalabe et al., 2010). Similar cases have been observed in Malawi where during woodland clearing before cultivation of settlement, predominant fruit trees (Parinari curatellifolia, Strychnos cocculoides and Uapaca kirkina) are customarily left uncut and scattered around homesteads or crop fields as well as in Tanzania, Zambia and Zimbabwe whereby Parinari curatellifolia and Uapaca kirkina are left in cultivated fields (Kalabe et al., 2010). This practice increase crop yields, income and savings resulting in change of wealth and soil improvements.

Agroforestry parklands display that they are rational land use systems developed by farmers over many generations to diversify production for livelihood, income generation and the minimization of environmental risks related to high climate variability.

The open woodlands known as savannah cover an area of approximately 103 billion ha in Africa (Cook and Grut, 1989). The savannahs are predominantly situated in the north and south of the equilateral rainforest belt. In Sahel, one third of the forage is produced by trees and shrubs. Camels and goats obtain much of their food from these sources. In the drier regions of the savannahs Acacia Senegal (gum Arabic tree) is one of the important trees. This tree produces pods and leaf fodder for livestock, fibre, and
wood. The tree improves the soil through its capacity to fix nitrogen, as well as useful for windbreaks in Sudan. This specie is thus further classified as a silvopastoral specie. Hence, it can also be planted in agricultural areas, where it can be intercropped. *Acacia tortilis* is another specie used by farmers in Africa to feed livestock and wildlife. It is a drought resistant specie that provides wood and animal feed.

In the Guinea type savannah in northern Ghana, shea butter (*Butyrospermum parkii*) and the West African locust bean/dawadawa (*Parika clappertonia*) are the most important trees in farmed parklands (Cook and Grut, 1989). Shea butter is important in the local diet, used as medicine, in cosmetics, soaps and cooking. The tree has a narrow crown, allowing the tree not to provide much shade on the crops around it. The *dawadawa* tree is a leguminous, nitrogen-fixing tree which improves the soil.

In drier Sudan type trees (*Acacia albida*, also known as *Faidherbias/Gao*) are planted in west Africa, Sahel as well as in Malawi as a soil improver (Cook and Grut, 1989).

The Australian specie *Grevillea robusta* ("silky oak" of "silver oak") was introduced as a shade tree planted in the coffee plantations of East Africa (Cook and Grut, 1989). Farmers appreciate this specie and use its leaves for mulching.

Swidden agriculture, is the traditional form of shifting cultivation in Africa. In the Comoros, farmers use *Cajanus cajan* or pigeon pea to preserve and enhance soil fertility (Cook and Grut, 1989). Pigeon pea is a nitrogen-fixing woody shrub which has the capacity to grow on very poor soils and in very dry climates. Pigeon pea protects and enhances the soil. Its woody stalks are used for fuel, the peas for food and pods and foliage for feed.

In Africa forests are reduced but the number of trees planted on the farms are increased. Therefore there is increase in spontaneous agroforestry. This is most evident in the densely populated highlands of east Africa, in Kenya, Rwanda and Burundi. Farmers plant trees for fuel wood, building poles, fruits, shade, fencing, timber, fodder, soil improvement and protection against wind.

The *taungya* agroforestry system was developed by the British in Burma during the nineteenth century and introduced in South Africa around 1880 (Daff, 2017). *Taungya* agroforestry is a system in which farmers or labour is able to plant crops in between
timber trees during the early stages of the establishment of forest plantation. It was an improvement of shifting destructive cultivation to the forest reserves in British India.

In Sri Lanka, the taungya agroforestry system is being practised, emphasizing on reforestation of land that is abandoned by non-resident cultivars. In this system *Tectona grandis* and *Eucalyptus camaldulensis* species are planted and intercropped with agricultural crops (rice, maize, plantain, chili and mustard). However, the area under this system in Sri Lanka is significantly decreasing due to lack of interest from farmers.

In east Africa an initiative was approached whereby dairy farmers grew fodder shrubs as supplementary feed. In Central Kenya dairy farmers planted shrubs (*Calliandra calothyrsus* and *Leucaena trichandria*) to feed their dairy herds (Daff, 2017), increasing milk production. In the Philippines, farmers grew a combination of improved fodder grass and trees (*Gliricidia sepium*) and this assisted then in improving their livestock and crop production.

Traditional agroforestry systems that been practiced in Tanzania are the Chagga home gardens (involves the combination of several multi-purpose trees and shrubs with food and cash crops and livestock occupying the same unit of land) in the north eastern Tanzania, the kagera in the home gardens of the Mara regions in north western Tanzania, the usambara (intercropping cardamom (*Elettaria cardamomum*) and black pepper (*Piper nigrum*) with trees, especially with Grevillea robusta) a traditional system in north eastern Tanzania, and the traditional wasukuma silvopastrol system called “nigitili” in western Tanzania (Msuya and Kideghesho, 2012). These agroforestry systems use multi-layered systems with a combination of annual and perennial plants, which imitate natural ecosystem (Msuya and Kideghesho, 2012).

The northern regions of Uganda from the parishes in Apac district farmers planted eucalyptus species in swamps to reduce flooding.

Alley cropping is practiced in humid lowlands as well as in sub-humid to semi-arid zones like Machakos in Kenya (Okullo *et al.*, 2003).

The practice of combining trees with pastures is widespread in various climatic zones throughout Central America, particularly in the wet lowlands, lowlands with prominent dry season and highlands (Steppler and Nair, 1987).
2.5.2 Agroforestry management in America

In the northern regions of Thailand, *taungya* agro-forestry systems are used by the farmers (Watanabe et al., 1988). Tree and crop combinations are used in the *taungya* system, such as tree species (teak (*Tectona grandis*), and fruit trees) and main crops (upland rice (*Oryza sativa*), maize (*Zea mays*) or sorghum (*Sorghum bicolor*)) which are inter-planted in the field. Furthermore, beneath the crops or fruit trees, different kinds of vegetable sub-crops (pumpkin, chili and beans) or cash crops (pineapple, mungbean or castor bean) are inter-planted. This then mitigates the high rainfall levels and extended rainy seasons in the south, and longer drought periods in the west, northeast and north regions.

The most common crops inter-planted with trees in the *taungya* system are upland rice in the north regions, cassava and kenaf in the northeast, maize and sorghum in the west and coffee or cashew nuts in the southern region. Therefore tree and crop combinations are changed depending on the season. Maize is thus usually cultivated in the rainy season, from May to August. After the harvesting of maize, sorghum is planted where the maize was grown in reforestation areas in the west regions. In the northern region maize and sorghum are occasionally mix-planted on the same land.

In the Central American regions mainly in lowland pasture with high rainfall, forestering of natural regeneration of *Cordia alliodora* was practiced (Budowski, 1993). A species which has high commercial value for its timber. This practice, is mainly observed in Costa Rica, Panama, Nicaragua, Honduras and Guatemala. It has also been observed in Tabasco (Mexico) and evident in the Amazon region of Ecuador, notably the Coca area. *Cordia alliodora* is a sun loving species that self-prunes and has a straight trunk with a small crown, permitting light penetration (Budowski, 1993).

In Costa Rica living fence-posts, mainly made of *Gliricidia sepium*, are used to fence-off pasture and crops. *Gliricidia sepium* is a medium-sized tree that grows 10 to 12 meters high. It is used for many other purposes including fodder, firewood, and green manure and intercropping. Furthermore, it provides edible fruits and flowers, reducing the stress on natural forests (Budowski, 1993).

In El Salvador some farmers have replaced traditional crops with *Gliricidia sepium* fallow (Kass and Somaribba, 1999). Every five to ten years, the trees are harvested for fuel wood, the area is burnt and used for other crops.
In the southern part of the department of Lempira (western Honduras), farmers use the Quezungal systems (Hellin, 1999). The system consists of naturally regenerated and pollarded shrubs and trees in relation with more traditional agro-forestry components such as high value timber and fruit trees. Plots of the system consists of three levels: trees (*Byrsonima crassifolia* (nance), *P. guajava* (guayab), *C. alliodora* (laurel) and *Diphysa robinioiides* (guachipilin)), pollarded trees and shrubs (*Citrus spp* (manderina), *Persea americana* (avocado), *Simarouba glauca* (aceituno) and *Cedrela odorata* (Spanish cedar)), and agricultural crops (*Zea mays*, *Sorghum bicolor* and *Phaseolus vulgaris*) (Hellin, 1999). The system is largely linked with smallholder farmers, and common on slopes of 10% to 25%. Honduras experiences two harvests per rainy season (Hellin, 1999). The *primera* (crops planted in April/ May and harvested in August/ September) and *postrera* (crops planted in August/ September and harvested in December. Farmers plant maize in the *primera* and beans in the *postrera*. Some farmers do not include the *primera* harvest and only cultivate in the *postrera* harvest to reduce the occurrence of pests and diseases. When farmers use the Quezungal system they do not burn their fields before planting. Vegetation is cleared by hand. The density of the trees and shrubs is managed ensuring that there is optimum shade for the agricultural crops and species are pollarded when crops are planted in the *primera* harvest and pruned in the *postrera* harvest. The pollarded and pruned material is spread throughout the plot as mulch and at times used as a fence.

*Mimosa tenuiflora* (carbon negro), a perennial tree or shrub native to the north-eastern region of Brazil, is used in Honduras in zones up to 1200 m elevation with 600-1500 mm rainfall per year with dry periods that last up to eight months (Kass and Somaribba, 1999). This tree is also used in Guatemala, El Salvador, Nicaragua and Brazil in agroforestry systems. During the fallow periods, *M tenuiflora* is used for fuel wood, fence-posts, charcoal production and cattle grazing during the dry season. Maize and sorghum are cropped after the fallow (Kass and Somaribba, 1999).

Traditional agroforestry systems practiced in North America include grazing in forests of the west United States (US), forest plantations of the southern US and alley cropping intercropping/ multi-cropping) with black walnut (*Juglans nigra L.*) in the Central US (Schultz *et al.*, 1995) and Midwestern and southern US (Garret and Buck, 1997). Tree rows in this system are spaced in order to consider the biological needs of intercrops.
Closer within row spacing’s supply greater protection of the site (e.g. erosion control) early in the rotation period. Silvopasturing is also common practice in the state of Washington, southern and west parts of the US and has considerable potential in the Midwest regions of the US (Garret and Buck, 1997).

Windbreak systems (Shelterbelts) are the oldest form of agro-forestry in the US. This system is being practiced in the northern, mid-western plains states (Kansas, Nebraska and Dakotas) and western states where they are used for stabilizing micro environments. Well-designed windbreak systems result in increased crop and livestock productions, reduce wind erosion, improves microclimates, snow retention and reduced crop damage by high winds. These systems are designed either as single or combined rows scattered across an area with spacing within the row that provide sufficient air movement, minimizing turbulence.

Kekchi Maya farmers in Belize use Tapado systems with crops (Kass and Somaribba, 1999). Farmers produce maize by traditional slash-and-burn systems and by a malahambre slash-mulch system on fertile soils along riverbanks. Similar combinations of these two systems are practiced by farmers as they transfer from wetter to drier areas in Panama and the Amazon (Kass and Somaribba, 1999). Farmers using this system consider it to be less hazardous than traditional planting in areas with irregular rainfall.

The Maya community of San Jose, Belize use a traditional type of slash-and-burn agricultural practice known as the milpa (Kass and Somaribba, 1999). In this practice the soil is left in fallow. Clearing is carried out during the dry season, using an axe and machete to keep in the field Woody species (Orbignya cohune) that are of interest to the community. The Orbignya cohune is resistant to fire once the lower leaves are removed. Burning occurs just before the first rains, at the end of April (Kass and Somaribba, 1999). Corn is the planted a few days after burning, to make use of the nutritive elements in the ashes.

The Bora, Amerindians of the Amazon in eastern Peru and southern Colombia subsist from swidden agriculture, fishing, collecting and hunting (Barton, 1994). Swidden agriculture is a traditional subsistence agroforestry system practised by the Amerindians which includes cutting and burning small plots of forest for crop production, followed by long-term fallowing of the land. They use both primary and
secondary forest for their swidden plots. Fallows are felled during the period of lowest rainfall and burned after drying. Useful palms and trees, as well as certain valuable timber species, e.g. Spanish cedar (*Cedrela odorata*) are spared during clearing. Coppice regrowth of certain species is also encouraged. The crop combination of a Bora swidden varies enormously with the needs of a family and labour availability. Generally, families will have six or more fields in various stages of succession to fallow. Those fields with less diversity tend to be abandoned earlier than those in which perennial tree crops have been introduced.

The Kayapo Amerindians of northern Mato Grosso and southern Para States (Brazil), reside in areas of maximum species diversity (Barton, 1994). Each zone will provide natural products and attract different game species at different times of the year. Their *swidden* plots are set out in the form of concentric rings; the major crops being sweet potatoes, yams and plantains. The centre of the swidden is dominated by sweet potatoes, a secondary ring begins with maize followed by cassava and sweet potatoes. The outer ring includes yams, cupa (*Cissus gongylodes*), bananas, pineapples, urucu (*Bixa orellana*) and fruit trees. Kayapo *swiddens* vary considerably, and crop combinations depend upon household labour availability, hierarchical obligations (communal fields whose surplus is distributed by the chief), personal preferences, ritual obligations (naming and death ceremonies) and internal markets.

The Ka’apor Amerindians inhabit a tract of dry land which is not subject to annual floods in the dense forest in northern Maranhao State, Brazil (Barton, 1994). Once a site has been selected a communal swidden is cleared and cultivars from the old site are transported to the new. Ka’apor recognize six major vegetational zones (or types of forest or manipulated forest): (a) house gardens; (b) young swiddens up to two years from burning; (c) old swiddens 2-40 years from initial burn; (d) old fallows 40-100 years from first burning; (e) mature forest and (f) swamp forest.

The Amuesha, which inhabit the tropical rainforests of the Palcazu valley of east/central Peru also practise a form of swidden agroforestry modified by their contact with European and the rest of Peru (Barton, 1994). Amuesha agriculture is characterised by diversity of cropping systems, which relate to particular soils, environments and managed fallows. They farm small pockets of fertile soil found on the slopes of the valley. They classify and choose land according to the soil's ability to support different
forms of vegetation, and fallow times reflect differential fertility status. All their fields are intercropped with a great diversity of minor crops.

2.5.3 Agroforestry management in Asia

South and Southeast Asia is described as the cradle of agroforestry in recognition of its long history of the practice of an array of systems under diverse agro ecological conditions (Kumar et al., 2012). Agroforestry in South Asia includes multifunctional home gardens, which promote food security and diversity; woody perennial-based systems furthering employment avenues and rural industrialisation; fertiliser trees and integrated tree-grass/crop production systems favouring resource conservation; and tree-dominated habitats, which sustain agro biodiversity and promote climate change mitigation strategies as well as parkland systems; agrisilviculture (the growing of agricultural crops with simultaneously raised and protected forest crops) involving poplar (*Populus deltoides* Bartram) and Eucalyptus spp. (Kumar et al. 2012).

Agro-horticulture system and agrisilviculture is widespread in Bangladesh, India, Nepal and Sri Lanka. Alley cropping is practiced by smallholder farmers in South Asia. Moreover, in the coastal tracts of India, Bangladesh, Sri Lanka and Maldives aqua forestry system is dominant. Parkland agroforestry systems is practiced in India and Pakistan, while shaded commercial crop production systems is prevalent in the mid and high altitude zones of India, Bhutan, Nepal, and Sri Lanka. Parkland agroforestry system is a type of agroforestry system in which large canopy trees are widely spaced in croplands or grasslands. The trees may be either planted or from natural regeneration (Kumar et al., 2012).

The cumulative temperatures and altering moisture regimes threatens ecosystem services as well as the availability of resources that supports the livelihoods of poor and indigenous communities. The application of indigenous knowledge by traditional communities helps societies to manage natural resources in a socially and culturally sound manner which encourages the protection of these resources. Furthermore, indigenous forest and pasture management practices have evolved from cultural norms, traditional values, collective behaviour, and community based institutions (MOSTE, 2015).
The Madanpokhara community of Nepal used local knowledge to collectively manage their forest, they had a set of rules and regulations that govern the removal of forest products, especially fuel wood, fodder, and leaf litter (MOSTE [n.d]). Harvesting was banned and strictly enforced until the forest cover stabilized. However, according to (Acharya and Baral, 2017) ownership of natural resources particularly land/forests, has always been a symbol of wealth, power, social prestige and security for most of the indigenous people, therefore there is complex relationship between indigenous people and local communities, their livelihoods and nature. Local people have developed sets of coping mechanisms to deal with water scarcity through centuries of interaction, experimentation and adaptation.

In China, agroforestry was practiced 1,700 years ago in the Shanyang County (Zhaohua et al. ed., 1991). To address the great shortage of timber experienced, local farmers were advised to plant a living fence of elm trees. The uniform elm tree belts grown not only provided enough timber to meet the local requirement but were also beneficial to the growth of crop plants.

The taungya system originates from in Southern China 300 years ago. In this system, villagers and sometimes forest plantation workers are given the right to cultivate agricultural crops during the early stages of forest plantation establishment. Cultivation is often allowed to continue until trees shade crops due to canopy closure. The system has been reintroduced recently in Southeast Asia (Zhaohua et al. ed., 1991). The multitudes of agroforestry systems that have evolved in Asia over centuries reflects the accrued wisdom and adaptation strategies of millions of smallholder farmers.

In the flat lands of northern China, they intercrop agricultural crops with Paulownia elongate; one of the fastest growing trees. Artificial Agroforestry Multiple Ecosystem is also practiced in the Lixiahe Flatland of China. Farmers also intercrop crops on forest glades; pisciculture in rivers, ponds and penstock, and grow hydrophilic crops such as fodder and lotus rhizome. All sum up to the agroforestry system where one component symbioses with another (Zhaohua et al. ed., 1991). Additionally, Forest-grass System in North Western Loessial Plateau and Desert Area is common, due to climate change in the area serious damage in the vegetation resulted in the of fuel wood, forage and timber, therefore forest grass system plays a key role in supplementing them (Zhaohua et al. ed., 1991).
The Hanunoo Mangyan of the Philippines’ island of Mindoro, practice shifting cultivation. They clear the forest for agricultural use, intentionally leaving certain trees. By the end of the rice-growing season, those trees provide a partial canopy of new foliage to prevent excessive exposure to the sun. Similar farming systems have also been common in many other parts of the humid lowland tropics of Asia (Conklin, 1957).

The Ifugao, indigenous people of the Cordillera region of the Philippine archipelago have practiced agricultural systems that nurture the land and the forest. Those include woodlots and multiple cropping in swiddens as an economic insurance in case of crop failure in the terraces (Dacawi, 1982). They also practice rice terraces forest – coupled agroforestry system, kaingin and multi-storey System. The rice terraces forest-coupled agroforestry system is known as "payoh" pinugo"/"hayokong"/"hino-ub" system in the region. The system include alteration of a sloping areas into rice terraces with a close proximity water source. The catchment is an undisturbed forest stand about 5 to 6 hectares wide, managed by either a clan, a family or a group of people using it. In addition, the kaingin called "uma"/"habal"/"inuman" is responsible for removing all vegetation including the roots or retaining selected species of trees (Dulay, 2015).

In West Java, three types of agroforestry systems are used, home garden (pekarangan), mixed garden (kebun campuran) as well as forest gardens (talun-kebun). The home garden agroforestry system describe it as a land use form in which several tree species are cultivated together with annual and perennial crops including livestock (Weersum, 1982). The mixed garden is a form of land use dominated by planted perennial crops, mostly trees, under which annual crops are cultivated. The talun-kebun is particularly a rotation system between mixed garden and tree plantation.

The dudukuhana system, also prevalent in the West Java region (Manurung, et al., 2006) are traditional farming systems divided into timber system, mixed fruit-timber-banana-annual crops system, mixed fruit-timber system, and fallow system. All types of dudukuhan are managed on an extractive basis, with few inputs.

2.5.4 Agroforestry management in Oceania

Indigenous folks from the Kingdom of Tonga in the central south west of Pacific Ocean, use various traditional agroforestry systems such as home garden style, slash and burn.
Home garden style involves interpolated arrangement, moreover in this system various crops and useful plants are cultivated under tree canopy. They allow farmers to harvest different kinds of staple plants throughout the year (Makino, 2003). Shifting cultivation or “slash-and-burn”), includes a highly diverse range of land use practices. It is practised in a variety of landscapes, from steeply sloped hilly areas to flat lands and low-lying valleys; and in a variety of ecosystems ranging from tropical moist forests to dry tropical forests and savannas, grasslands, and seasonal floodplains (Thrupp et al., 1997).

Customary agroforestry systems operating in Papua New Guinea may be classified into four broad categories, defined principally by geographic region, although each has many variants within the region (Kanowski et al., 2014). The Highlands agroforestry complex is a combination of sweet potato and casuarina (mainly *Casuarina oligodon*) in a number of complex agronomic and cultural associations across that region. The lowland to mid-montane agroforestry systems are dominated by assemblages of annual and perennial food plants and trees in different combinations. The coastal agroforestry systems are the most diffuse of the four described, largely because coastal populations have historically been relatively small and coastal environments are varied. Lastly, the islands systems are dominated by a range of fruit and nut tree species in association with a number of annual and perennial food crops. These systems are known for being flexible with adaptive management. However, Papua New Guinea landowners have proven very skilful at incorporating new elements or components (e.g., cocoa, coffee) well-suited ecologically, that provide products which contribute either to the subsistence or cash economies, and that can be maintained through intermittent rather than intensive management (Kanowski et al., 2014).

In New Zealand and temperate regions of Australia, agroforestry systems have been developed over the last 30 years to address the problems of land degradation. Agroforestry systems in Australia include scattered trees in pastures, tree belts and woodlots (Smith, 2010).

Agroforestry systems in Gunung Salak Valley, West Java, Indonesia include home gardens, fruit tree system, timber tree system, mixed fruit-timber system and forest understory system (Rahman et al., 2016). Home garden system refers to the system where tree are grown in the home compound consisting of a grouping of plants which
includes trees, shrubs and herbaceous plants. This is a long traditional standing system in Gunung Salak Valley, West Java, Indonesia. Timber tree system is rotational based on planting of a selected timber species, timber trees are harvested at a time when their diameter reaches a size to yield useful timber. They are either immediately replaced through natural regeneration, planting, or the land use is reverted to seasonal crops for a few years before being planted to trees again (Raham et al., 2016). Fruit tree system are established in agriculture fields, through planting of fruit trees and understory crops. Generally, this is a permanent system, as the fruit trees are productive for a long time period. The individual fruit trees are established and maintained as integrated components of the system continuously over time with over-mature trees being individually replaced whenever needed. This maintains a high, closed canopy of trees with dense undergrowth and high levels of agro-biodiversity (Rahman et al., 2016). Lastly, forest Understory System are used on a limited scale, primarily only for household consumption. Farmers cultivate in the forest area bordering homesteads and farmland with only a small management input, little disturbance to the forest and no appreciable deforestation. After harvesting the crops are replanted.

2.6 **TOPIC 1.6. INTEGRATED WETLANDS AND FISHERIES MANAGEMENT**

2.6.1 Integrated wetlands and fisheries management in Africa

A case study of farmers’ strategies for adapting to climate vulnerability in the low valley of Ouémé showed that local people have developed a remarkable ability to adapt to climate threats, or in some cases have turned threats into opportunities. From fishing practices to agricultural techniques through agro-fishing practices, people of low valley of Ouémé managed to take advantage of their natural vulnerability through adaptation strategies mainly based on local knowledge (Yaro, 2010). The Ouémé valley people of Benin take advantage from succession and regularity of flooding and recession periods in floodplains. Indeed, the finger ponds dug mainly in flood-plains serve as refuges for wild fish migrating during the flooding. At low-water levels, these indigenous species of fish are tamed into the holes and become easy prey to farmers. More so, in the coastal zone, according to the men, most farmers who previously were
into cultivation of cassava and maize have now changed to onion cultivation, since onions are easier to store and sell later for more money (Yaro, 2010).

Communities of Illubabor and Western Wellega zones in Oromia Region, Ethiopia, play a key role in coordinating wetland management and sustaining the benefits from wetlands (Dixon, 2008). Wetlands provide a variety of hydrological and ecological benefits, such as the recharge and discharge of groundwater, flood control and retention of sediment, as well as maintaining biodiversity of specially adapted flora and fauna (Dixon, 2001). Farmers in Ethiopia use these wetlands as reservoirs of moisture during dry periods, as well as to cultivate maize much earlier in the season than on the uplands. Therefore, maize crops are harvested before maturation (during its ‘green’ phase). Wetland plants are also used by farmers as indicators of changes in soil fertility or hydrological conditions (Dixon, 2001). The kemeté plant (*Leersia hexandra*) is related with the degradation of wetlands. If these plants start occupying the wetland, farmers become aware that they need to actively rehabilitate the normal flooding regime in order to increase wetland fertility. Comparably the inchinne plant (*Triumfetta pilosa*) is used as an indicator of increasing fertility, therefore its development in a wetland is considered as the end of a fallow period by farmers. Indigenous knowledge of these plant indicators represents a critical way in which the local community can evaluate the state of their wetland and consider suitable measure to ensure wetland use is sustained.

In Rwanda, wetlands are used because of their large water reserves, lower erosion risks and natural fertility. There are four types of vegetation on Rwanda’s wetlands (Mbabazi, 2011). First, wetlands dominated by the *papyraie*. They are characterised by abundant water and the vegetation of *Cyperus Papyrus* (Paper reed) thus containing water throughout the year. Second, wetlands dominated by *Cyperus Latifolius* (Njekenjeke). They have low water content below the soil surface, making them suitable for cultivation during the dry season. Third, wetlands dominated by shrub-like vegetation. This vegetation rarely retains any water, however water is available during rainy seasons. Fourth, wetlands dominated by grass. They are used during the dry season.

The Kilombero Valley in Kilombero District, Morogoro Region, Tanzania contains the largest freshwater wetland at low altitude in East Africa (Kangalawe and Liwenga,
Most farmers of the Kilombero Valley use wetlands to grow rice, maize, bananas, vegetables and cassava, either during the rainy season or in the dry season. In the late 1900s, most of the livestock keepers in Signali village began herding their livestock in the wetlands as a result of the availability of good pastures and water found in the wetlands.

2.6.2 Integrated wetlands and fisheries management in America
In the Altiplano of Peru water bofedales (areas of wetland vegetation that may have underlying peat layers) are a key resource for traditional land management at high altitude (Fonkén, 2014). Because they retain water in the upper basins of the cordillera, they are important sources of water and forage for domesticated livestock during the dry season, as well as biodiversity hotspots. The knowledge on their and management is passed down through generations (Saylor et al., 2017). Bofedales are increasingly threatened by overgrazing, peat extraction, mining and development of infrastructure.

2.6.3 Integrated wetlands and fisheries management in Asia

2.6.4 Integrated wetlands and fisheries management in Oceania
Indigenous ecological knowledge is deeply rooted in the customary land and sea tenure institutions in Oceania. Consequently, governance and management systems are based on cultural and historical practices that have evolved over the years, to regulate the use of, access to and transfer of local resources (Aswani et al., 2012). For instance, forms of marine territoriality, such as common property rights-based systems, are arranged and approved by stakeholders (Cohen and Foale, 2011). The tenure right identify the particular users as having exclusive rights over resources and it has the ability to exclude non-members from accessing and using them. Rights of inclusiveness are distinguished via a number of socio-cultural rules based on birth
(primary rights), marriage and residence (secondary rights), and the direct transfer of rights by traditional authorities (Aswani et al., 2012).
3 THEME 2: SEMANTICS

Objective: to explore the appropriate terminology for the technologies and practices under discussion.

This document report endeavours to utilise the benefits of identification, collation and inclusion of different knowledge systems as part of climate change adaptation. It does however conflate terms such as indigenous knowledge, community knowledge, local knowledge and community knowledge. While those terms are related, they have significant differences, also which if used interchangeably causes confusion and exclusion. In addition, in many instances the term indigenous is also used as catch-all to include other types of knowledges. Again this is problematic as indigenous knowledge refers to a specific kind of knowledge system associated with indigenous peoples only. Since these terms provide essential guidance to the discussion at hand in the document their use and definition needs revision. In the sections below, we briefly introduced most of those terms.

3.1 DISTINGUISHING BETWEEN LOCAL AND INDIGENOUS KNOWLEDGE.

3.1.1 Local knowledge

Naess (2013) defines local knowledge as follows: “local knowledge can be defined as the unique knowledge developed over an extended period of time and held by a given society in a specific location”. Sillitoe (1998:204) also presents a definition of ‘local knowledge’, but specifically linked to the development context. For him local knowledge “may relate to any knowledge held collectively by a population, informing interpretation of the world”.

In both of these definitions local knowledge is presented as knowledge that is held by a particular group of people over time in order to understand the world they live in. Further along in their arguments both of these authors also suggest that local knowledge is shaped by social and cultural traditions and that knowledge and skills as well as ways of managing environments are linked to worldviews embedded within the social and cultural context in which the knowledge is held.

It is important to note that local knowledge is not exclusively linked to indigenous peoples, however it may include them. Berkes et al. (2000) in their discussion on
knowledge systems also makes a clear distinction between local communities and indigenous communities. As such, if one were to use the two terms interchangeably one may lose any examples that do not emanate directly from indigenous communities.

3.1.2 Indigenous knowledge

Mascarenhas (2004:5) defines indigenous knowledge as “the total sum of the knowledge and skills which people in a particular geographical area possess, and which enables them to get the most out of their natural environment”. An important point emphasised by Mascarenhas here is that the knowledge and skills are passed on down from previous generations and are then adapted and added by the new generation as way to equip them with survival strategies in a constant adjustment to changing circumstances and environmental conditions.

The term indigenous knowledge is however extremely value laden. For example, Heyd (1995) argues that for most authors the term ‘indigenous’ is problematic as the term infers that it may only be knowledge held by indigenous people where the term indigenous stands for “aboriginal, native or autochthonous, though; that is, it is used to make reference to the knowledge of the people who comprise the descendants of the original inhabitants of a land” (Heyd, 1995:63). In this sense, by using the term indigenous people or knowledge one would exclude all other kinds of knowledge that do not adhere to these restrictions. As such one can see how indigenous knowledge can be understood as local knowledge, however the converse cannot be true.

The terms indigenous knowledge and traditional knowledge is often used interchangeably without much confusion, however the term “traditional” is also considered value laden. In this case, authors (Sillitoe, 1998; Berkes, 1993; Berkes et al., 2000; Naess, 2013) warn that the use of the term might evoke notions of hierarchy related to ideas about who or what might be civilised thus juxtaposing that which is considered traditional with that which is considered modern, equating modern with civilised. We would therefore suggest that using the term indigenous as catch-all for local, traditional and indigenous knowledge may cause unnecessary confusion as well as negative labelling.
3.2 CLARIFYING THE USE OF TEK AS ALTERNATIVE

As an alternative to the interchangeable use of local and indigenous in relation to knowledge in the document we propose the use of the term ‘traditional ecological knowledge’ (TEK). TEK is a well-established term within the literature on knowledge systems utilised by people in relation to their environment. Berkes (1993) presents a unified definition of TEK based on a number of definitions from diverse authors:

“TEK is a cumulative body of knowledge and beliefs, handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment. Further, TEK is an attribute of societies with historical continuity in resource use practices; by and large, these are non-industrial or less technologically advanced societies, many of them indigenous or tribal”.

Another definition of TEK that builds on the Berkes (1993) definition comes from Gómez-Baggethun et al (2013: 71). They argue that TEK “consists of the body of knowledge, beliefs, traditions, practices, institutions, and worldviews developed and sustained by indigenous, peasant, and local communities in interaction with their biophysical environment (Gómez-Baggethun et al., 2013: 71).

Using TEK as defining framework one avoids eliminating knowledge that is not explicitly labelled ‘indigenous’, in addition it will alleviate the confusion between exactly what is ‘local’ knowledge. In addition, for the purposes of this document the knowledge systems and practices identified should be explicitly linked to people and their relationship, management and understanding of their natural environment. The TEK definition provides this. TEK also retains important characteristics such as knowledge that is handed over from one generation to the next; historical continuity in relation to the keepers and knowers of knowledge; knowledge linked to a distinct group of people; and includes other forms of knowledge such as local and indigenous where they are explicitly linked to the environment. Lastly studies on TEK have shown its contribution to improving livelihoods, sustaining biodiversity and ecosystem services; and building resilience in social-ecological systems (Berkes, 1993; Berkes et al., 2000; Folke, 2004; Gómez-Baggethun et al., 2013).

In order to be able to identify relevant TEK examples, we suggest the use as the following characteristics (adapted from Berkes, 1993) presented below as identifiers.
By using these characteristics as identifiers one also solves the methodological predicament of rationalising the choice of knowledge examples used in the document. The suggested characteristics are:

- TEK is mainly qualitative especially in its translation into data (as opposed to quantitative);
- TEK has an intuitive component (as opposed to being purely rational). In other words, the question is not whether something can be proven, rather what effect does it have on behaviour and practices;
- TEK is holistic (making sense as a whole) as opposed to reductionist;
- TEK has embed within it morals and does not operate value-free;
- TEK is often linked to spiritual aspects of life and being;
- TEK is based on empirical observations and accumulation of facts by trial-and-error;
- TEK is based on data generated by resource users themselves and not by a team of researchers;
- TEK is based on diachronic data, in other words, long time-series on information on one locality and not synchronic data (short time-series over a large area).
4 THEME 3: GOVERNANCE

Objective: to identify factors influencing an enabling environment for the adoption of the practices and make recommendations

4.1 TOPIC 3.1. LAND TENURE SYSTEMS

Traditional or ancestral land that indigenous and traditional peoples inhabit represents the fundament of their cultures. It is estimated that traditional and indigenous peoples, who only constitute to about five per cent of the world’s total population, occupy about 20 per cent of the world’s land surface (Oviedo et al., 2000). These peoples have managed and shaped their surroundings over centuries, adapting their livelihoods to very specific local natural, physical and climatic conditions. Many of the ancestral territories that indigenous and traditional peoples dwell in comprise sacred natural sites represented in the form of mountains, rivers, lakes, caves, single trees or forest groves, coastal waters and entire islands. Traditional and indigenous peoples are tightly connected to their land, not only through their livelihoods but also through spiritual bonds (Below et al., 2010).

However, in many cases, land tenure and access rights of indigenous communities are not legally recognised (ibid). As a consequence, their land and resources are often exploited and encroached by outsiders. This insecure situation further “acuminates the already challenging situation many of these peoples live in, and may result in severe implications to their vulnerability and capacity to adapt.” (Below et al., 2010). For instance, in times of acute climatic crises, people often shift their agricultural activities to more favourable areas. The Makushi of Guyana, for example, move their savannah homes to forest areas in times of droughts (Salick and Byg, 2007). If this traditional way of adaptation to environmental variability is restricted or denied these people might not be able to cope with environmental stresses and be at acute risk. Consequently, it is crucial to protect land tenure and access rights of traditional and indigenous peoples and to reward them for the goods and services their lands provide (Below et al., 2010).

Similarly, women and young people have not been lucky enough to inherit landed property or do not have financial resources to invest in landed property ultimately lose out. Assets alone are not enough, but the social and economic conditions that allow
people to use these assets to earn a decent livelihood are. There is a reduction in interest in agriculture among youths, which has led to migration becoming a cross-cutting issue affecting all agro-ecological zones, with significant consequences for the receiving areas in urban and agricultural frontier zones (Yaro, 2010). Many more women are poorer than men in all regions, which is a reflection of traditional patriarchal norms translated into current access patterns to resources and privileges enjoyed by the different sexes. Traditional inheritance systems give precedence to men over women (Levin et al. 1999; Quisumbing et al., 2001; Awumbila and Ardayfio-Schandorf 2008).

The seasonal distribution of rainfall has implications for local knowledge, because it is so important for agriculture and for domestic water supply. People are eager to determine when rains are going to start during the first season (because it is shorter and they need to plant as early as possible) and during the second season. Seasonal rainfall variability influences family well-being as well as agricultural production. If a season brings very little rain, people have to travel farther to fetch water from streams, ponds, and wells, a considerable burden that falls almost exclusively on women and children, who are also responsible for a large amount of agricultural labour (Orlove et al., 2010).

4.1.1 Land tenure in Africa

4.1.2 Land tenure in Asia

In the Maluku Islands of Eastern Indonesia, over the last two decades the traditional tenure practices known as *sasi* has been reinterpreted and reinvented to support the Indonesian government and NGOs to promote sustainable development, conservation and social equity. *Sasi* is a body of customary law that asserts social control over the access to forests, fields, and orchard lands and, to a lesser extent, the marine environment. This is done through the imposition of a temporary prohibition on entry or harvest. While the practice of *sasi* has over time been manipulated and politicised, the essence of it has remained and has be reinterpreted as an embodiment of
Moluccan culture towards ensuring sustainable local based resource management as well as the economic empowerment of the local community (Zerner, 1994).

4.1.3 Land tenure in America

4.1.4 Land tenure in Oceania

4.2 Topic 3.2. Institutional Arrangements (or Lack of)

4.2.1 Institutional arrangement in Africa

4.2.2 Institutional arrangement in America

For the Omushkego Cree Indian people living in the area of the James and Hudson Bay area in Northern Ontario, the transmission of knowledge from one generation to another is essential for survival and livelihoods. The practice of “learning by doing” instead of traditional educational structures is revered by the Cree. In this system youngsters are encourages to learn by watching and gradually coaxed to repeat the observed actions. These children are therefore taught from a young age about harvesting and hunting, also called “bush knowledge” which has been essential in ensuring the skills and knowledge is handed down through the generations. (Ohmagari and Berkes, 1997).

4.2.3 Institutional arrangement in Asia

In Indonesia, the Dayak people in East Kalimantan utilise their traditional ecological knowledge to cultivate simpukng or forest gardens. Simpukng is an important part of
the Dayak traditional farming system where they manage a secondary forest in which selected species of fruits, rattan, bamboo, timber and other plants are planted. The Dayak believe that that all natural resources, including forests are essential for human existence and as such land management is inherently infused with aspects of human life such as religion, kinship, the social and the economy. *Simpukng* produce food for consumption, medicines for treating illness, firewood for cooking, timber for construction, commodities for trade, and other products necessary for rituals and ceremonies. *Simpukng* is however generally considered to be a common property resource rather than individual asset and as such brings together knowledge while at the same time builds local networks that becomes essential is times of strife during periods of natural disasters or hazards. (Mulyoutami et al., 2009).

The local community of the Rote Ndao District in Indonesia has reinvented the *Papadak/hoholok* which is essentially a land management system made up of ethics and solidarity values that culminates in a set of rules and behavioural regulations in terms of agricultural practices. The papadak/hoholok is traditionally used for the regulation of agricultural resource management in paddy fields and drinking water, but has recently also been applied to marine resource management to alleviate the current lack of control and oversight of marine activities. The *papadak/hoholok* is however more than a set of rules, it in fact binds communities and neighbours together in terms of the shared resources to ensure that all actions are in the best interest of the group rather than the individual. It also seeks to bring control and management of local natural resource into the hands of locals rather than government institutions. In this way the community becomes more resilient in the management of its own resources (Oktavia et al., 2018).

In the Dindori and Chhindwara districts, Madhya Pradesh of India, communities pursue instructions of their culturally approved leader “*Vaidya*” and some ritual specialists who assess the natural resources use and manage any conflict associated to pasture lands and local biodiversity use (Singh and Sureja, 2007). The cultural elected leader (*Vaidya*) plays a prominent role in land use patterns for grazing as well as in community conservation strategies. Basically, the *Vaidya* map, re-establish ecosystem boundaries, and demarcate land by fixing the stones and rules for use and conservation of seasonal
water in small ponds and aquatic sources, thus contribute to the survival of livestock species and sustainability of natural resources. Besides, infringement of these cultural rules calls for censure and small scale fine by the Vaidya.

4.2.4 Institutional arrangement in Oceania
5 THEME 4: YOUTH ATTITUDE, TABOOS, ALTERNATIVE LIVELIHOOD, ETC

Objective: to identify other factors affecting the sustainability of the technologies and practices.

5.1 TOPIC 4.1. THE YOUTH’S ATTITUDE TOWARDS TECHNOLOGIES AND PRACTICES

There are many causes or reasons as to why Indigenous knowledges/Traditional Ecological knowledges are marginalised (Ocholla, 2007):

- the knowledge is not codified nor systematically recorded and therefore difficult to transfer or share;
- the knowledge lives solely in the memory of the beholder and is mostly oral, meaning that unless transferred, it dies with the beholder;
- the knowledge is embedded in the culture/traditions/ideology/language and religion of a particular community and is therefore not universal and therefore difficult to globalise;
- the knowledge is mostly rural, commonly practised among poor communities and is therefore not suitable in multicultural, urban and economically well provided communities;
- the knowledge is perceived to be primitive and old-fashioned, and therefore has no value;
- families and communities are becoming increasingly disintegrated and globalised, and;
- Some issues raised do not have any scientific basis.

5.1.1 Youth’s attitude towards technologies and practices in Africa

In Tanzania, Ngono River basin, Muleba and Missenyi districts, traditional healers were highly respected by the community, however this is no longer the case. Similarly, due to the lack of respect of the traditional culture and taboos that exists in the communities, most of the elders who are the custodians of this knowledge are less willing to share this knowledge with the younger generation. It was found that the
current generation is not interested in indigenous knowledge due to number of factors, including modernization (Theodory, 2016).

Currently, the indigenous knowledge of is in danger of being lost if it is not well documented as community elders, who are the main custodians of this knowledge, are swiftly decreasing within the community. Of critical concern is the growing perception among the younger generation of indigenous knowledge as outdated and inefficient, with little potential for incorporation into current development policies \( \text{ibid} \). Fabiyi and Oloukoi (2013), go further to argue that, even though the realities and the confirmed efficiency of indigenous knowledge, some issues have yet to be addressed. For example, “scientific efficiency and the transferability of indigenous knowledge from generation to generation.” Since these knowledge systems have not been documented they can easily be forgotten. In the past, indigenous knowledge was transferred to younger generations through folk tales, communal festivals and age grade initiations. However, all these oral traditions are considered to be local and outdated by the younger generations today, which means that this knowledge will never be learned by the youth in the communities \( \text{ibid} \).

Turkana pastoralists in northern Kenya, particularly the women, have developed a traditional knowledge of the local flora and their uses. For example, trees are important because they provide fuelwood, building timber and household utensils. Certain important trees are protected by custom (Barrow, 1996). In the long dry season the women cut small branches to feed livestock and collect pods and fruits of certain trees (for example, Acacia tortilis) for fodder and food. The Turkana communities also use tree products for medicines, some of which have important clinical properties (Barrow and Mlenge, 2003). More so, to manage their wet, dry and drought time grazing areas, the Turkana tribe have a number of institutions for natural resource management, which, with their accompanying rules and regulations, are under the control of the Turkana elders, and, in some cases the women \( \text{ibid} \).

Traditional communities have a long history of responding to climate change variability. Indigenous and newly introduced adaptation practices have helped communities cope with both current climate variability and future climate change.
5.2 Topic 4.2. Taboo, cultural, religious and spiritual beliefs

Indigenous knowledge on environmental change has been shaped by experiences of community inhabitants, and it is further indissolubly linked to culture-space, place, meaning and identity (Berkes, 2009). Prior the existence of central governments, local communities were governing their resources through customary regulations. Taboo, cultural, religious and spiritual beliefs continues to govern natural resources in many communities around the world. Through roots in cultural and religious spheres, traditional practices have helped communities benefit from the traditional systems and minimised climate change impact.

5.2.1 African taboos, cultural, religious and spiritual beliefs

According to the Ilaje tribe in Abereke, Ondo state, Nigeria, it is considered taboo to curse someone at night in their own village, and that any violation would bring ocean floods the next morning which could be very devastating for the entire community (Fabiyi and Oloukoi, 2013). When the “lawbreaker” confesses, their fine would be to provide a fowl which would be killed and its blood poured into the river at the shrine as the initiates eat the fowl on behalf of the gods. When this is done, the flood would recede and the culprit would be pardoned. Notably, it is considered dangerous to deny an accusation by the gods, because the entire village could be wiped out. This knowledge has long helped the fishermen decide when to fish and when to prepare for devastating floods (ibid).

Communities in Ghana often times impose fishing related taboos in order to curb the large scale withdrawal of certain fish species. For example the Tema and Tesie communities at the Sakumo lagoon in Ghana have a taboo in place that prohibits the use of draw nets and other nets of mesh size smaller than 2.5cm. The Ningo community at the Djange lagoon, also impose a taboo on the use of poles sticks and draw nets for fishing. In this way, large scale over harvesting of fish is curbed as well as the preservation of habitats are conserved (Colding and Folke, 2001).

In Nigeria local communities that reside within the transgressive mud beach zone on the coastline, rely on their religious beliefs, culture and past experiences to deal with coastal flooding. The local population in the study area include the Ijaws, Ilajes and Itshekiri communities, while they are primarily Christian each community has elaborate
traditional religious practices and beliefs which include veneration of ancestors and respect for water spirits especially the Olokun (the god of the Atlantic). These religious practices ensure that the community members have a personal relationship with the water spirits. Prayers and good behaviour will ensure the good graces of the water spirits which in turn will ensure less flooding. Moreover, these beliefs provide a structure for communally sanctioned behaviour that ensures sustainable practices amongst community members. In addition, these communities have developed local skills and abilities that has been handed through generations to predict for flooding and prepare for it. Through their interactions with the environment and their yearly and monthly experiences with flood, they have realized the significance of some signs that precede flooding in Nigerian coastal areas. These signs are related to their ability to read the weather conditions and to their knowledge about the peculiarity of each month in their local calendar, the state of the moon, the consultation of local gods and some ecological indicators (Fabiyi and Oloukoi, 2013).

Indigenous knowledge has helped farmers in OR Tambo District in the Eastern Cape in their farming practice and drought risk reduction. Farmers use indigenous knowledge to forecast droughts. The proliferation of small red ants during dry periods indicates a persistent drought (Muyambo et al., 2017). As a result, in the past village leaders would conduct rituals with the belief that after the ritual the rain will come. The villages in OR Tambo would announce a chief meeting where village leaders would set a date and time to go up to a sacred mountain such as Ku-Qwempe to conduct ritual to request rain from the ancestor. In the mountain they would perform a traditional dances known as Imingqungqo or umxhentso. People would carry along traditional beer and would slaughter one of their cattle. It is believe that it will rain after the ceremony.

5.2.2 American taboos, cultural, religious and spiritual beliefs

In the Andean mythology, the toad is believed to be associated with reproduction and fertility (Saylor et al., 2017). Furthermore, they are also used to forecast weather conditions. An increase in the number of toads is an indication that the rainy seasons is approaching (Saylor et al., 2017).
Religion and religious ceremonies play an important role in the way farmers recognize climatic variability. Farmers in Tlaxcala Mexico believe that “the weather is the will of God”, suggesting that any scientific efforts used to forecast weather precisely would fail (Eakin, 1999). Farmers believed that if the rains were late or have stopped for some period, the community should go onto the fields and pray for better weather.

5.2.3 Asian taboos, cultural, religious and spiritual beliefs

In India, there are a number of sacred groves that is revered by the local populations. Culturally a sacred grove is set apart from forests for spiritual and religious purposes. These habitats are regulated by means of taboos that provide protection to all forms of vegetation. The grove is considered sacred by virtue of the fact that a deity or their spirit resides in the grove. However some scholars (Gadgil and Vartak, 1976) argue that sacred groves are a legacy of the traditional Indian shifting cultivation system known as jhum. There are a number of sacred groves currently in India, amongst others: Khasi Hills (Assam), Aravalli ranges (Rajasthan), Western Ghats, Bastar and Sarguja (Madhya Pradesh) and the Chanda District (Maharashtra). With rapid deforestation in India sacred groves provide an important source of forest produce for local communities. (Gadgil and Vartak, 1976; Colding and Folke, 2001.)

In the Sariska region, India, to cut the peepal (sacred Fig Tree, *Ficus religiosa*) and banyan trees (*Ficus benghalensis*) is considered as heavenly offensive Spirits of the ancestors reside in those trees represent the tie between the world of the living and the world of the dead, and a link between the physical and philosophical dimensions (Alexander et al., 2016).

In Uttarakhand, central Himalayan region of India, during *Sravana* (fifth month of the Hindu calendar) a number of social groups stop consuming fish, poultry and meat (ra, 2010). Similarly, community leaders of Maluku Island in Indonesia, use customary management to ban fishing activities. These traditional methods ensure that everyone has equal access to natural resources. Moreover, traditional communities with their collective knowledge of biosphere, are exceptional observers and interpreters of change in the environment.
5.2.4 Oceanian taboos, cultural, religious and spiritual beliefs

Indigenous people have used traditional knowledge, skills, customary laws, taxonomic systems, and traditional practices to sustainably utilize their rich natural resources as a basis for adaptation to change (Lauer and Aswani 2010).

Chiefs among the clans of Tikopia in the Solomon Islands impose sporadic taboos on the harvesting and consuming of particular resources such as yam, taro, breadfruit and coconut. These taboos may be imposed weekly to seasonally by the Chief during a public meeting. During the taboo or closure period coconut trees for example are protected during seasons where they are not bearing well. The taboo will ensure that the trees are maintained until they sprout and they can be transplanted. The taboos are enforced by the chief by declaring his totem animals such as bats and eels as informants and deterrents. The institution and enforcement of such taboos support conservation practices and resource management. (Chapman, 1985; Colding and Folke, 2001).

Among the Miriwoong, an indigenous community who reside in the township of Kununurra in the East Kimberley region of north-west Australia, the environment is positioned as sentient and communicates with the Miriwoong. It is therefore considered of great importance to listen to nature as it speaks to the elders of the community. A good example of this is the seasonal calendar that has been developed by the Miriwoong. The seasonal calendar is a physical manifestation of traditional ecological knowledge consisting of observations and adaptations to changing environmental conditions that has been collated and interpreted over many Miriwoong generations. The seasonal calendar provides essential knowledge about the ecosystem dynamics over a considerable period of time as well as its response to changes and guides their resource management and use (Leonard et al., 2013).

In Viti Levu (largest island of the Fiji), it is believed that if a fisherman catches a Na Ki (bandedtail goatfish *Upeneus vittatus,* and unknowingly brings it to the village, there will be a tsunami soon afterwards (Janif et al., 2016).

In Covalima, Liquiça, and Viqueque, Timor Leste, killing sacred snakes (*Rainain Samea Lulik*), cutting down sacred trees (e.g., teak, bamboo and gmelina) or removing sacred
stone (*fatuk lulik*) is forbidden, especially from river banks (Hiwasaki *et al.*, 2014). If landslides occur, it is believed that such hazards were brought by people breaking these rules, and rituals to ‘apologise’ to nature’ for the human behaviour that caused hazard – such as *Monu ain ba lulik* (‘apologise to nature’) – are held, in addition to reforestation of the affected area. The ceremony reinforces respect for nature and ensures that villagers follow the sacred rules, if not, they will get nature’s curse and disasters will occur. Disasters provide an opportunity for social cohesion, respect for nature, and awe for nature. Rituals and ceremonies, along with customary laws that govern behaviour, engender and reinforce respect for the environment as well as strengthen social cohesion are conducted to enable communities to better face and respond to the impacts of climate change and other hydro-meteorological hazards (*ibid*).

In response to water shortages during long dry seasons or droughts, communities in Laco-Mesac and Ulmera (Timor-Leste) organise rituals to bring rains that are led by the elders in the sacred places (Pinto, 2014).

### 5.3 TOPIC 4.3. ALTERNATIVE LIVELIHOOD STRATEGIES

#### 5.3.1 Alternative livelihood strategies in Africa

In northern Burkina Faso, Sahelian community, migration seems to be one of the key strategies adopted by many farmers in times of drought, although difficult to leave their own communities, migration provides a source of income (Barbier *et al.*, 2009).

In the Guba district of Benishangul Gumuz Region, Ethiopia, many households used gathering of wild plant produce as a coping strategy during food shortage. Most people would go to the forest for a few days to gather edible fruit, leaves and tuber, and return once they have collected enough for their families (Fentaw, 2013). Besides the feeding of wild fruits, leaves and tuber can diversify the nutrition of the households as almost all households consume a staple food of sorghum porridge. In addition to their own consumption, few people engage on collection and selling of wild food (*ibid*). Moreover, as part of the coping strategy during food shortage, the male from each
household is responsible to hunt wild animals and take the flesh to their family. Children and women also engaged in small animal hunting like bird species and others (ibid).

Culturally, Guba people share the available cooked food at home with others. They prepare food in one's house with round turn base and eat together. For instance, if today food is prepared in one individual home, all the neighbours would be invited to share the meal (Fentaw, 2013). The following day, it will be the turn of another family to prepare the meal of the neighbourhood. During trying times, families that deplete their reserves of sorghum crop, will survive by eating meals cooked by other families (ibid). This is a form of a coping strategy implemented by many Guba people particularly during intense climate variability.

In other instances, when communities faced short term shocks/problems they depleted productive assets by selling them to mitigate short term challenges. Furthermore, seasonal migration was one of an alternative of coping mechanisms. Many would migrate to the neighbouring country, Sudan and be employed as daily labourer with better wage rate than in Guba. Families back home would receive remittances from the migrant until they return to their home land (Fentaw, 2013).

In the Benishangul Gumuz Region, Ethiopia, there are few places where gold is found. According to Fentaw, (2013), some households practice traditional gold panning as a source of income to purchase food crops and other basic needs. Other coping strategies during food shortage include daily labour, charcoaling, firewood selling, water fetching for the better people etc. to earn money to buy food crops.

Fentaw, (2013), notes that “changes in farm management include a wide range of adjustments in land use and livelihood strategies that go beyond the usual agricultural practices available for coping with constantly varying biophysical and socioeconomic conditions.” In the face of increasing climate variability and gradual changes in average climatic conditions, farmers may re-evaluate the crops and varieties they grow, and may consider shifting from farming to raising. They may also introduce different livestock breeds that are more resistant to drought.

Around the world, many countries have changed their cropping systems due to climate variability. According to Kurukulasuriya and Mendelsohn (2006), “crop selection
among African farmers varies significantly in cooler, moderately warm, and hot regions.” Farmers select sorghum and maize-millet in the cooler regions of Africa; maize-beans, maize-groundnut, and maize in moderately warm regions; and cowpea, cowpea-sorghum, and millet-groundnut in hot regions (Kurukulasuriya and Mendelsohn 2006). For example, in a case study covering villages in three South African provinces; Khomele in Dzanani District Limpopo Province, Mantsie in Lehurutshe District, North West Province and eMcitsheni, in uThekula District, KwaZulu Natal, it was found that during dry spells farmers tended to reduce their investment in crops or even stop planting and focus instead on livestock management (Thomas et al., 2007). As climate change scenarios predict an increase in climate variability in many parts of Africa, farmers probably will turn to this temporary coping strategy more frequently and thus turn it into adaptation.

Furthermore, the study also found that, farmers are increasingly trying to exploit the spatial diversity of their landscape. The villagers tried to gain access to land that gives good yields during times of drought because there is a water source for irrigation reachable at plot level (Thomas et al., 2007). By comparing cases in the Roslagen area of Sweden and the Mbulu Highlands of Tanzania, Tengö and Belfrage (2004), discovered similarities in practices aimed at dealing with temporary drought at field level. For example, farmers in Sweden and Tanzania both use cover crops to enhance seedling survival. On the other hand, “controlling erosion by using contour planting, mulching, and the construction of cut-off drains and sluices” was common only in the Mbulu highlands, where the fields are on a slope (Tengö and Belfrage 2004).

Though the weighting of different factors is problematic, smallholder farmers’ urgent need to control the widespread risks in their livelihood system clearly is a strong driver of diversification. While commercial activities beyond subsistence agriculture often do reduce the risk of suffering as a result of climate hazards, sometimes they also have the opposite effect. Paavola (2004), reports that excessive use of natural resources in the Morogoro region, south-eastern of Tanzania undermines sustainable land use. In the face of drought people diversify into the production of charcoal, which increases rates of deforestation, and into artisanal mining, which leads to soil erosion and water depletion (Paavola, 2004). According to Bryceson (2002), increased diversification has
influenced the division of labour and decision making power within smallholder households and has caused a widening of wealth differentials between households.

Furthermore, evidence from case studies shows that local or indigenous knowledge can beneficial or problematic in the context of climate change adaptation. Siedenburg (2008), analysed local knowledge about agroforestry practices in the context of rapid environmental change in the Shinyanga Rural District of Tanzania. He found that some smallholder households do not actively foster the regeneration of key farm-based natural resources, and he concluded that variations in local knowledge may be a key determinant of their use of this practice. Furthermore, his study found that Shenyang’s farmers were unaware of the beneficial impact of trees and calls for providing them with tailored information about agroforestry and the role of trees for groundwater and soil conservation. In contrast Mbilinyi et al., (2005) emphasize that existing indigenous knowledge of rainwater-harvesting technologies in the Kilimanjaro region of Tanzania is an important asset for designing and implementing irrigation technologies in the future.

Local networks have multiple functions in reducing vulnerability and enhancing adaptive capacity. According to Campbell (1999), farmers and herders of the Kenyan Kajiado District rely strongly social cohesion to adapt to dry drought. Many have relied on assistance from relatives or friends as a response to the severe drought. Osbahr et al., (2008) found that in the Gaza province of Mozambique, “traditional labour exchange mechanisms have become more popular in the last 20 years.” A local practice called Kuvekala, which allows those looking after other peoples’ livestock to keep the firstborn animal as payment, had become more commonplace since the late 1980s (Osbahr et al., 2008).

Thomas et al., (2007) found in their study from South Africa that collective action has emerged as an important way to enhance adaptive capacity. eMcitsheni village in Kwazulu-Natal province has established a maize cooperative to address marketing risks and reduce production and transportation costs. In Khomele village in the Limpopo province used existing cooperative structures to search collectively for new sources of agricultural income such as small-scale horticulture, poultry, and egg schemes (Thomas et al. 2007).
In Central Plateau of Burkina Faso, diversification of livelihood sources, particularly in sectors that are not rainfall-dependent, is an important strategy for reducing household vulnerability to climate risk. Most households rely on cash income from various economic activities to purchase grain when their own production falls short. Men may practice masonry, butchery, tailoring, or bicycle repairing, for example; while women may brew beer, sell cooked food or sauce ingredients, or make shea butter, baskets, and other items for the market. Kongoussi’s lake and Bonam’s reservoir also provide opportunities for fishing and dry-season production of vegetables, maize, and rice for additional income (West et al., 2008).

The mountains surrounding Kongoussi have gold-bearing ore deposits, which enable local households to engage in artisanal gold mining during the dry season. Because of their greater access to roads and markets, households in Kongoussi and Bonam can engage in trade, while Rollo’s relative isolation limits the opportunities for off-farm income. Nonetheless, drought and famine compromise the viability of off-farm income generation activities by reducing the supply of water and raw materials, the availability of money to invest, and the demand for products and services. (ibid).

In the Mantheding Community in Limpopo Province, South Africa indigenous plant resources make up an important part of the communities’ livelihoods. Indigenous plant resources provide rural communities with non-timber forest products that provide energy, food, shelter and medicine. Indigenous plant users in the rural communities have developed selective management methods to sustain plant resources. The most common management methods are restrictions on the cutting of green plants, harvesting of some species during certain seasons, exclusive harvesting of the leaves of certain species and collection of lateral roots from medicinal plant species. Indigenous plant species are sustained through selective cultural practices where the plant users collect the plant materials through observance of local management practices. Such cultural practices are important in the conservation of biodiversity, rare species, protected areas and ecological processes (Rankoana, 2016).

In northern Mali, many local strategies can be considered as coping mechanisms, because they are reactive to external events. In Tibuktu region, Tin Aicha and Ras El Ma communities, though women are currently apply coping strategies, they consider it important to develop long-term strategies, such as investing in children’s education.
However, because of their exclusion from decision-making and increasing workloads (particularly as a result of men’s migration), opportunities are lacking (Brockhaus et al., 2013). Children’s education was considered as the most important strategy by women of both communities. Their long term objective is to give children new livelihood opportunities, preferably independent from natural resources. But, because of the workforce needs in the household, girls must often realize domestic tasks and boys look after goats or sheep rather than attend school. This shows a trade-off between coping with current problems and adapting in the long-term (Brockhaus et al., 2013).

Additionally, charcoal production is part of the strategies of Iklan women in the farmer community, who invest generate incomes in long-term strategies (e.g., children education) and increase their social integration. In the pastoral community, Illelan women argued that charcoal production does not match their high perceived social status, this limits their diversification opportunities (Brockhaus et al., 2013).

The Dassenech and Nyangatom communities in Ethiopia, use a combination of indigenous coping strategies to help them withstand environmental change. These methods are suited for their culture and have passed on from generations to generations (Gebresenbet and Kefale, 2012). For example, during extended droughts, community members sell their livestock. Additional measures comprise, diversification of activities, such as involvement in business, casual labour for income generation, to exchange livestock against cereals and to graze the livestock beyond political boundaries during dry periods.

Moreover, changing diets with climatic situations is identified as a food security strategy. An illustration is provided through a study on communities around the South Omo river (Ethiopia) where crops and milk dominate after harvest, meat dominates in dry periods, and fish (which is a taboo during normal periods) is only eaten during periods of serious drought. Also, migration is another alternative, beside the use of migration as a flood protection strategy, pastoralist communities migrate in order to find “greener” areas for their livestock and access to water (Gebresenbet and Kefale, 2012).

During periods of drought, some communities in Northern Ghana, intensify the picking and processing of Shea nuts and dawadawa by local women, while the men cut grasses for sale. Shea nuts are processed into oil and soap while dawadawa (the seeds of Parkia
biglobosa, otherwise known as the African Locust Bean Tree) is processed into oil (Yaro, 2010). At the peak of the hunger period, people depend on the use of Shea butter and the leaves of some edible plants. They boil the leaves and then add Shea butter, which enables them to cope until the early crops are harvested (Yaro, 2010). While in the Teso region of Uganda, community folks would harvest termites and wild fruits and vegetables for food (Egeru, 2012).

As seen from the above examples, climate change is one of the biggest challenges facing humanity across Africa. Be it an increase in temperature, less rainfall, unpredictable weather changes, Ethiopia and most East African countries whose economies are mostly reliant in rainfed agriculture are particularly feeling the effects of environmental change. Their various indigenous strategies helped them to build resilience against the negative impacts of climate variability.

Pastoral and agro-pastoral communities react to environmental shocks or stressors in a number of ways. Most families within communities experience similar amount to climatic stressors, livelihood outcomes vary greatly, both within and between communities due to different access to strategies (Naess et al., 2010). The community of Gao and Mopti regions of Mali, have adopted several livelihood strategies for the impact of environmental change. In the 1990s, the Gao community, has developed “small irrigated village perimeters and construction of dykes for water management” (Naess et al., 2010). This strategy has positively impacted the community, in terms of having better control of the Niger River water levels, improved rice yields and agriculture residues for livestock. The main livelihood for these communities depends greatly on the climate. Without the right amount of rainfall in certain areas during the year, harvest and livestock are threatened. While all communities have similar degrees of exposure to similar climatic stressors, the impacts on livelihoods vary greatly between the different regions due to varying access to strategies.

During Harvesting, farmers of the OR Tambo District in the Eastern Cape reserve big maize cob to build round huts known as Isiswenye or Intanyongo (Muyambo et al., 2017). The grains stored in those huts are used as seed in the next growing season. Also, after a good harvest of maize and sorghum, farmers keep some of the harvest in big water tanks, in preparation of the drought periods. Farmers would also dig a big
deep hole in the middle of the kraal (homestead) as a means of storing excess food or production, this would prevent thieves from gaining access to the food (ibid).

Treepreneurs (people who make income creation through growing indigenous trees in exchange for goods and services) Buffelsdraai reforestation project in EThekwini Municipality have been assisted by indigenous knowledge to confidently participate in identification, harvesting, and propagation of indigenous tree seeds (Dinga et al., 2017). These include prior harvest preparations such as the use of other traditional medicines to protect one from venomous animals in the forest. These traditional medicines are referred to as "izihlungu". These traditional blends (izihlungu) are said to repel snakes, therefore the treepreneurs do not have to wear protective gear, but rather use these protective repellents that are readily available in nature. Such repellents may include ingestible mixtures or burnt materials and even topically applied home-made solutions.

In Zimbabwe, farmers, especially women in Nyanga, Chipinge, Mudzi, Chivi and Gwanda districts, undertook many actions to mitigate drought and these resulted in at least some level of food security. The following are some of the measures employed: Permaculture; helps farmers prepare for drought through land use designs that enhance crop diversity and water conservation (Altieri and Koohafkan, 2008). Water harvesting; farmers harvest water from rooftops and divert water from natural springs into tanks. This ensures that they have a substantial amount of water stored up. In case of a drought, the stored water will be able to sustain them for about five months depending on the volume of the tank. The water is also used for supplementary irrigation of vegetables and crops. Infiltration pits; some farmers dig infiltration pits along contours (ibid). Water collects in the pits during the rainy period. When the weather becomes dry, as in the case of a short period of rains, the water infiltrates underground and is used by the plants. Crops can grow up to maturity by using this conserved moisture. Farmers’ experience shows that even if there are only five days with rain in the whole rainy season, the crops will reach maturity using conserved and harvested water in the pits (ibid).

Additionally, granaries; most farmers store food to be used in case of a drought. They have a specific granary stocked with grain (sorghum, millets, and maize for a shorter period of time), especially those resistant to post-harvest pests. Drought-tolerant
crops; many farmers prefer the use of traditional grains such as millets and sorghums that are more drought-resistant than maize and therefore give a good yield even with very little rain. Farmers also prefer specific crop varieties for drought seasons, such as an indigenous finger millet variety (*chiraufe*), a cucurbit (*Nyamunhororo*), as it ripens fast, and an early maturing cowpea (*Vigna unguiculata*) variety (Altieri and Koohafkan, 2008).

5.3.2 Alternative livelihood strategies in America

In both Mexico and Brazil, reforestation is an important management strategy that increase carbon stocks in ecosystems. Forest products provide safety nests for local communities when agricultural crops are unsuccessful as well as hydrological services such as: base flow conservation, storm flow regulation and erosion control (Locatelli *et al.*, 2010).

5.3.3 Alternative livelihood strategies in Asia

The Bisnois of the Thar Desert in India endeavour to manage their resource base through the management of a keystone process tree species, *Prosopis cineraria* which is a leguminious tree. This tree helps to fix free nitrogen and enrich the soil, and this provides ideal conditions for crops to grow under the shade of the trees. The trees also provide fodder while the branches provide fencing material and firewood while the pods are eaten by both cattle and humans. This kind of multiple species management results in soil fertility and crop protection in an otherwise hostile environment. As desertification is said to increase in some areas due to the effects of climate change, multi-species management may provide useful solutions (Berkes *et al.*, 2000).

In north-east India, the maintenance of more than 40 crops in a shifting cultivation landscape of different varieties enables indigenous communities to survive through difficult weather conditions (Nakashima *et al.*, 2012).
5.3.4 Alternative livelihood strategies in Oceania

In south-west Kimberley, Western Australia Miriwoong people, and other Australian Aboriginal groups have developed a variety of strategies to cope with the climatic variability such as resource sharing, group mobility, fire management, and harvesting practices. Miriwoong people use management of natural resources centres on customary rules based on weather conditions and seasonal indicators contained within their seasonal calendar. In Indonesia there are regulations that serve to prevent and mitigate hazards such as landslides, floods, and coastal abrasion, and strengthen social relations within communities (Hiwasaki et al., 2014).

In preparation for long periods of storms, people of Rapu –Rapu Island in the Philippines preserve food by digging a hole in the ground and placing a root crop like cassava inside the hole and refilling the hole with soil. The stored root crop which is prevented rotting, can last a month; thus proving food security during long periods of storm (Hiwasaki et al., 2014). Root crops grow underground and this practice is a natural way of preservation.

Prior to cyclone season, Elders from Naselesele village, Taveuni Island, encourage the community to use their local knowledge to prepare for such extreme weather events (McNamara and Prasad, 2014). For instance, locals are encouraged to plant kumala (sweet potato) before December so that there is always food in case of a cyclone, which can destroy staple root crops (such as taro and cassava) and fruit trees. Wild cassava can also be found in and around the plantations and is a good crop to rely on in case of food shortages.

In Kimbe, Papua New Guinean, villagers plant different crop varieties to increase chances of food availability during drought; while in Bulolo village, banana, cassava and Taro (Colocasia esculenta) are used as disaster crops since they survive in floodwater. Villagers wrap the bananas in leaves to protect them from water and birds (Sithole et al., 2015). Taro is cultivated in drains dug in the flooded soil. In addition, cassava and bananas as a staple in times of drought. Traditionally, during dry periods, villagers in the Papua New Guinean also survive on meat of a wild bird (Wembel) found in the grassland.
5.4 OTHER PRACTICES

5.4.1 Other practices in Africa

In the Guba district of Benishangul Gumuz Region, Ethiopia, women and children are the most affected by the impacts of climate variability and change-induced hazards, as their primary role is to carry out the “routine” of household activities. The increase of environmental change has now created further burden, thus making them even more vulnerable to the impacts (Fentaw, 2013).

In many parts of the world, persistent droughts have led to an increase in forest fires and desertification and as a consequence, contribute to a lack of fuelwood which plays an important role in indigenous and traditional people’s livelihoods (Macchi et al., 2008). Indigenous communities such as the Dayak of Borneo in Indonesia, the Baka Pygmies of South East Cameroon and Bambendzele of Congo have implemented a number of adaptation strategies, for example, when there is lack of fuel for cooking, community members reduce their intake of warm meals. However, this has had health implications particularly because, during hot seasons, germs multiply at high rates (ibid). More so, a decrease in the availability of water and fuelwood have had particularly serious implications on women and children. Notably, women from these traditional communities, apart from being involved in the care of children and the elderly, are also in charge of household food production and water and firewood gathering (ibid).

A change in climate may further increase the time necessary for completing these errands as the availability of water, vegetation and fuelwood may decrease. For example, a lack of firewood and safe water could prompt these communities to take their children, especially girls, out of school, in order to help their mothers to complete these tasks (ibid). Macchi et al., (2008), goes further to write, women from these traditional communities are expected to be particularly affected by the effects of environmental change and as such, “their unequal involvement in reproductive work, their frequently insecure property rights and access to resources as well as of their reduced mobility due to caring for children and the elderly in situations of stress,” are
some of the factors aggravating their particular vulnerability (ibid). Indigenous women continue to be vulnerable to the effects of climate change which may often add to their already marginalized situation.

5.4.2 Other practices in Asia

In the Terai area of Nepal, before floods come, women take their assets and livelihoods in higher places, sometimes, even their livestock. Those who have enough resources increase the platform level of their houses or homestead to protect their belongings from damage. They also build community shelters. Women farmers also switch to cultivating crops that can be harvested before flood season. Others grow rice varieties that survive above water when the floods come. Even the seedbed preparations and seed selection are altered to ensure crop survival (De Chavez and Tauli-Corpuz, 2009).

Climate change related food insecurity may result in especially high health risks for women as they often eat last and least, making them susceptible to illness, with more new-borns facing malnutrition (ibid). Longer distances and increased time for women to look for water, food and firewood often lead to girls dropping out of school as their help is needed in their families. The loss of education has lifelong impacts and results in a lower chance of them claiming their rights. Additionally, increased violation of women’s and girl’s rights in the context of climatic variations have also been documented, for example, in the case of pastoralist communities trading their daughters at ages as young as eight years old in order to replace livestock loss from drought (ibid).
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