Harnessing Floods to Enhance Livelihoods and Ecosystem Services in Gash Area, Sudan

Volume III:

Ecosystem Services and Benefits

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1. Introduction

An ecosystem is a dynamic complex of plant, animal and micro-organism communities interacting as a functional unit. Examples of ecosystems include deserts, wetlands, rainforests, grasslands, and cultivated farmlands. Human societies derive many essential goods from natural ecosystems, including food, animals, fodder, fuel wood and pharmaceutical products. These goods represent important and familiar parts of the economy.

Ecosystems benefits and services include food, freshwater, climate regulation, protection from natural hazards, erosion control, pharmaceutical ingredients and recreation. Ecosystem benefits are integral part of development. Forests, grasslands, freshwater, and other natural ecosystems provide a range of services that are not recognized in economic accounting systems, but are vital to human welfare, including water flow and water quality regulation, flood control, pollination, decontamination, carbon sequestration, soil conservation, nutrient and hydrological cycling.

Gash community came into being after most ecosystem services had been in operation for hundreds of years. The resources in Gash create ecosystem processes that include various species of animals, different type of foods: the biological, chemical, and physical interactions between components of an ecosystem (e.g., soil, water, and species). These processes produce benefits to people in the form of water, land, and reductions in erosion, among others. Food such as animal meals, egg milk, sorghum, vegetables, onion and fruits are of vital important for human life. Fresh water (ground water recharge) and mineral resources (clay and sand soils) are essential. Also animal skins are being used as inputs in the manufacturing of leather and leather products.

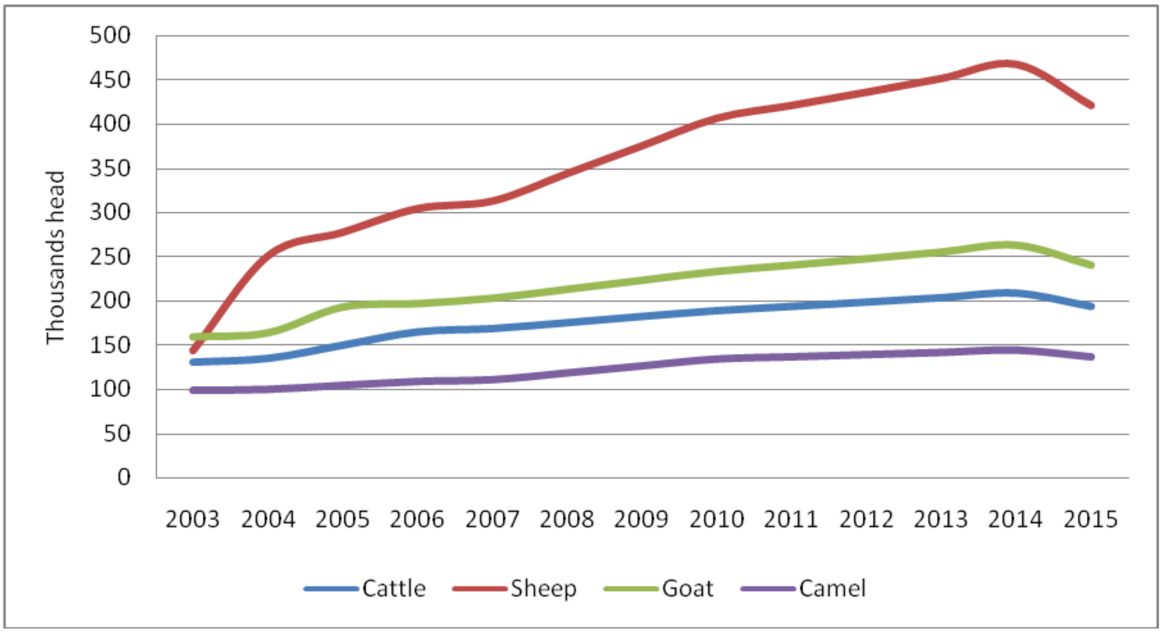
2. Importance of flood plains for livestock in Gash

Gash flood plain provides an increasing number of livestock with water and feeds. Animals at Gash flood plain feeds from the agricultural bi-products and free range land irrigated through uncontrolled flood. Gash flood plain sustains rangelands and local forestry, and helps recharge groundwater, thus providing drinking water for humans and livestock (FAO 2010). It provides human beings with the required domestic water (ground water recharge) and drinking water for livestock. The flood plain in Gash, renew the soil annually and this encourages good vegetative growth of plants. It constitutes an ideal situation for the agricultural production and livestock. Farmers produce fodder to feed the livestock and as cash crop. Thus, the flood plain provide a multitude of benefits to livestock (ecosystem services); for example, Gash flood plain regulating climate and supporting nutrient cycling, and soil formation and deposition. The forest and rangeland in Gash are sustained by Gash flood. It supports local community with building materials. Flood plain in Gash region, contribute significantly in food security and improvement of local economy. It creates labour opportunities (farming, marketing and grazing) and hence contributes in poverty alleviation (Figure1).

Captured by Eltigani Bashier (August, 2015)
Figure 1: Gash flood enhance livelihood and contribute in local economy

2.1 Gash is a home of diverse livestock

The total animal population (Figure 2) served by Gash flood plain equivalent to 3.5 million Animal Units (AU). One animal unit requires 1.08 ton of herd feed. This means the flood plain provide the livestock by 3.78 tons of herd feed annually. In the past pastoralist has either camel or sheep or both but now it has been observed that most of pastoralists have different types of animals to resist against climatic change. Arashie cattle are found mainly in Gash delta (the main spate irrigation source in Sudan). Grazing is practiced in the Gash Delta in Sudan since 1930s. The delta is also a home of diverse of livestock (Figure 3) including a large number of animal types (Table 1).



Source: Ministry of agriculture and animals, Kassala state
Figure 2: Gash flood plain serve growing animals

Figure 3: Diverse livestock in Gash

Table 1: Type of animals and their characteristics

Animal	**Characteristic**
Cattle	Daily water required for one cattle is 16/litre/day. One cattle produces about 3 to 5 litres of milk per day for around 5 months and is considered mainly as beef cattle. The average weight of the adult is ranging from 200 to 300 Kg. The Erashi breed of cattle is considered as dairy breed which can produce up to 10 litres of milk daily for about 5 months.
Desert sheep	Daily water required for one cattle is 4/litre/day. Sheep in Gash are desert sheep with average weight of about 30 to 40 Kg live weight and characterized by good quality meat.
Goats	Daily water required for one cattle is 4/litre/day. Goats are scattered all over the delta and graze freely around the settlement. They are kept for their milk and meat as house hold animal.
Camels	Daily water required for one cattle is 7/litre/day. Camels cross the Gash delta from Red Sea Mountains, some of them never leave the delta and its surrounding. The milk production of camels around Gash delta is estimated to reach 5 tons of milk per day most of the year.

The animals in the Gash flood plain are completely owned by pastoralists and agro-pastoralists. The pastoralists are categorized in three pastoral groups: nomads (30%), transhumant (20%), residents (40%) and refugees (10%) (Figure 4). The pastoralists of the area are estimated to be 37,000 members; about 7500 of them is heedless, dealing with animals as workers.

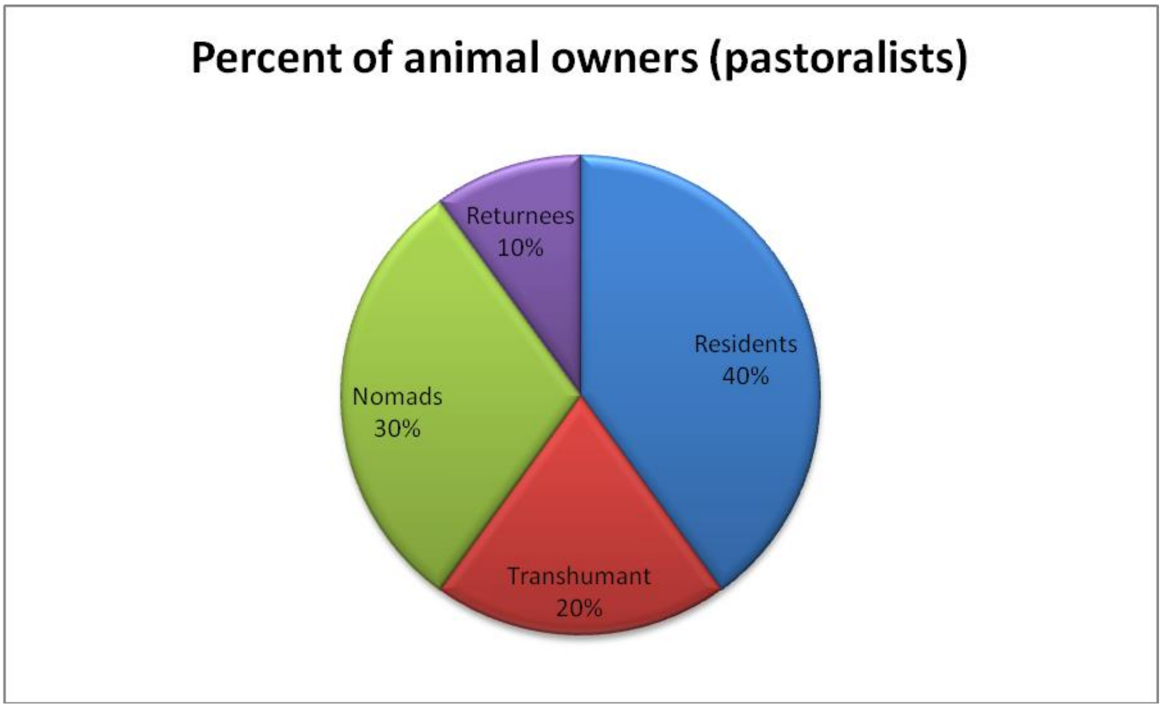


Figure 4: Pastoral groups in Gash

2.2 Gash flood plain provides livestock with fodders

Population in Gash flood zone, are pure agricultural dependant. Indigenous people said their standard of living is getting better with irrigated land and animals because of water provided by Gash River. The fodder production is highly recommended in irrigated and flood schemes to secure part of the animal feeds through agriculture. The fodder plants produced in Gash are of high production of dry matter, high nutritive value to meet animal's requirements and tolerant to several cuttings. Because of excellent Gash environment, it is possible also to cultivate annual legumes with sorghum to create a post crop rich pasture as well as acquiring the soil fertility from the nitrogen fixation which is a legume plant advantage.

2.3 Gash flood provide livestock with water

Gash flood plain flat land help in water distribution to allow benefits to livestock to continue to deliver a multi of benefits to the livestock. It provides water as a resource for direct use for livestock. Livestock requires water for drinking and may be cooling but the amounts required differ according to the type of animal, the method of rearing and the location. Gash flood plain provides an increasing number of livestock with increased water demand as animals search for feed. On an average, the annual drinking water requirement for livestock in Gash is about 3000 m^3 and services require another 500 m^3 (Figures 5). The co-existence of livestock maximizes the benefits of the flood plain. Existing agricultural practices involves the important role of livestock in the farming system in Gash. In turns livestock used for ploughing and bund building (Figure 6). It has been observed that**,** the farming systems in Gash are completely livestock based farming, (Table 2).

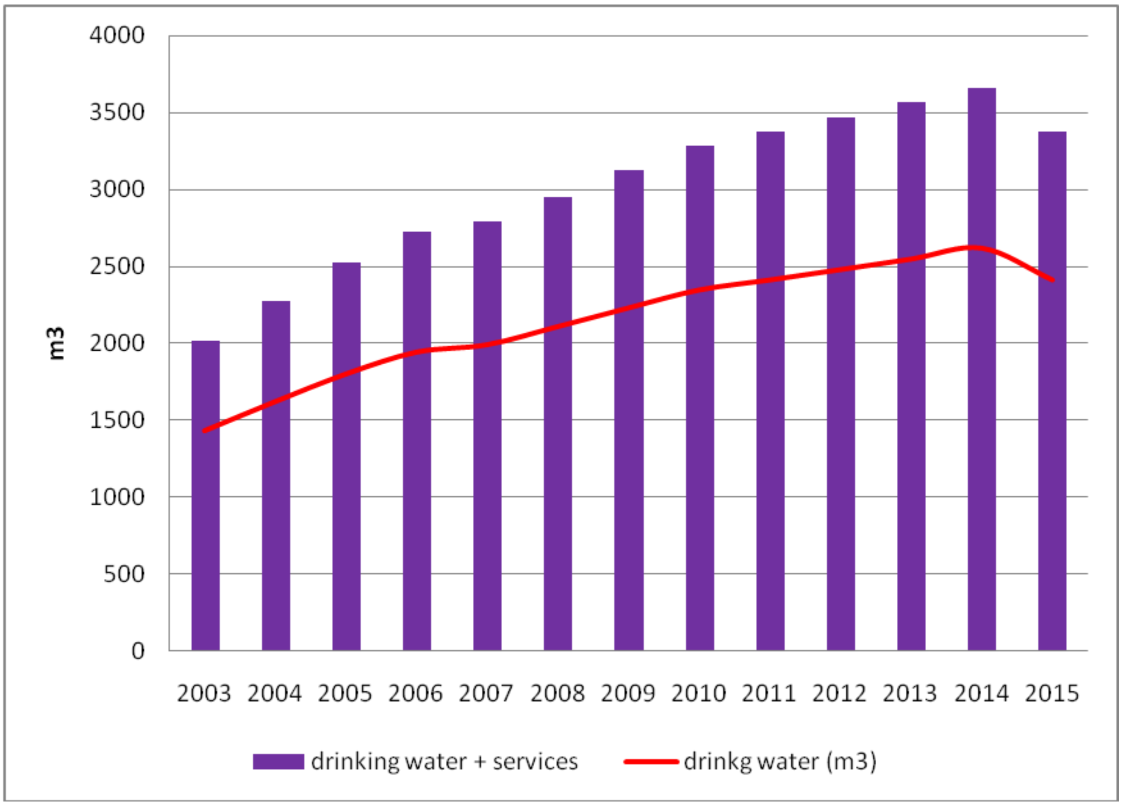


Figure 5: Annual drinking water and water services required by livestock in Gash

Figure 6: Animals used for ploughing

Table 2: Livestock based farming in Gash

	Livestock link
Nomadic pastoralism	Pastoralists establishing their camps on the Gash flood plain, around urban areas where emergency food supplies may be obtained. Male members travel with the livestock while the rest of the family remains behind.
Agro-pastoralism	This system is characterized by reliance on livestock for social status and perceived wealth. A narrow range of crops is grown at subsistence level on the Gash flood plain and the terminal fan, and in other areas such as Gash river overflow course to the west where moisture is available after flooding or rains. The herd composition is dominated by cattle that migrate over the rangeland relying on natural grazing and browse after the rains. Small ruminants are confined to the areas around the camps and water points.
Interaction between livestock and crops	Interaction between livestock and crops is limited to grazing crop residues after harvest. Fodder crops are not generally grown although animals let into crops to forage in periods of feed shortage.
Tenant farming system	The farming system has relied on a rotation where only one third of the net command area is cropped and irrigated each year to match the quantity of water diverted from the Gash river flood and hence the remaining land used by livestock as natural grazing.
Horticultural farming system	It is becoming an increasingly significant component of the land utilization on the Gash flood plain and involves perennial irrigation. Water is abstracted by pumping from wells sunk on the shallow aquifers on land that is not inundated by flood. The horticulture farming system has the lowest livestock-crop interaction of the remaining farming systems in Gash

3. Link between flood management and biodiversity, natural vegetation, ... etc

Gash flood is closely linked to biodiversity and natural vegetation. It renews the soil annually and this encourages good vegetative growth of plants. Flood is depositor of local biodiversity because it collects seeds from a large catchment area of about 21000 square kilometres and deposits them in moist soils and may feed Gash wetlands that are rich in species. Gash River is often unexpectedly rich depositories of vegetation. Natural species of vegetation are of considerable value and may provide an additional source of income to local communities e.g. Mesquite. Grasses and shrubs sustain livestock populations, while trees used for various purposes such as woods and charcoal. In Gash, the mesquite trees, grassland and clay soil cover 19.15%, 10.05% and 19.25% respectively (Abuelgasim et al, 2011).

Gash River brings about 5 to 13 million tons of sediment annually at Kassala. The river slope reduces remarkably and gradually deposits the rich silt and various seeds in its course at the lower Delta. These seeds and organic rich silt enhance the field as it provides good environment for various types of trees, shrubs and other vegetation. In the north and west where the rainfall is lower the vegetative cover is poor and includes scattered acacia trees and short grasses and shrubs. On the clay soils in the northern reach of the Gash flood plain and the terminal fan where the water table is shallow, the vegetation is denser (Figure 7) and a significant area is covered with semi-ever green woodland. Gash flooded areas have ecosystems with a great biodiversity of plants, animals and birds. Biodiversity in Gash can be seen during flood time (temperature is nice and humid is high). Then wetlands considered home for biodiversity. The spate fields, lakes and ponds are an excellent abode for highly important species of trees, birds and vegetation.

Multi human activities in Gash modify the landscape, such as poor farming systems, deforestation, and random animal breeding practices. These human practices degrade Gash watershed and reduce the amount of water available downstream. Land escape change tends to exacerbate soil erosion and reduce the soil water-holding capacity, and decrease the recharge of groundwater and existing surface water storage capacity, through siltation and sedimentation of rivers and reservoirs that subsequently result in water scarcity over time. In addition, the diversion of rivers for agricultural (irrigation) or industrial purposes deprives rivers and lakes of their usual flow, contributing to water scarcity in their hinterland.

Figure 7: Dense vegetation in Gash

3.1 Gash river flood recharging groundwater

Gash River provides the state with around 560 million m^3 of water per year during its two to four months of heightened flow. It originates in Eritrean plateau with height of 10000 ft (3000 m) above sea level, and entering Sudan plane at Allafa border of height 535 m, and flow in distance of 80 km, making delta height to 400 m (Ishag, 2012). The rock unit in the area are the Basement complex, Clay of the plain, and Alluvial deposits of the Gash River. Gash aquifer consists of two aquifers with isolated connectivity, sand and gravel that were deposited by the River Gash flood on the surface of the bed rock forming three sub-basins: the upstream aquifer (2- 4 km width), the middle (area of Kassala) up to 8 km width, and downstream aquifer of 4 km width. The storage of water in this aquifer depends on several reasons mainly the annual surface flow of the Gash River (Figure 8).

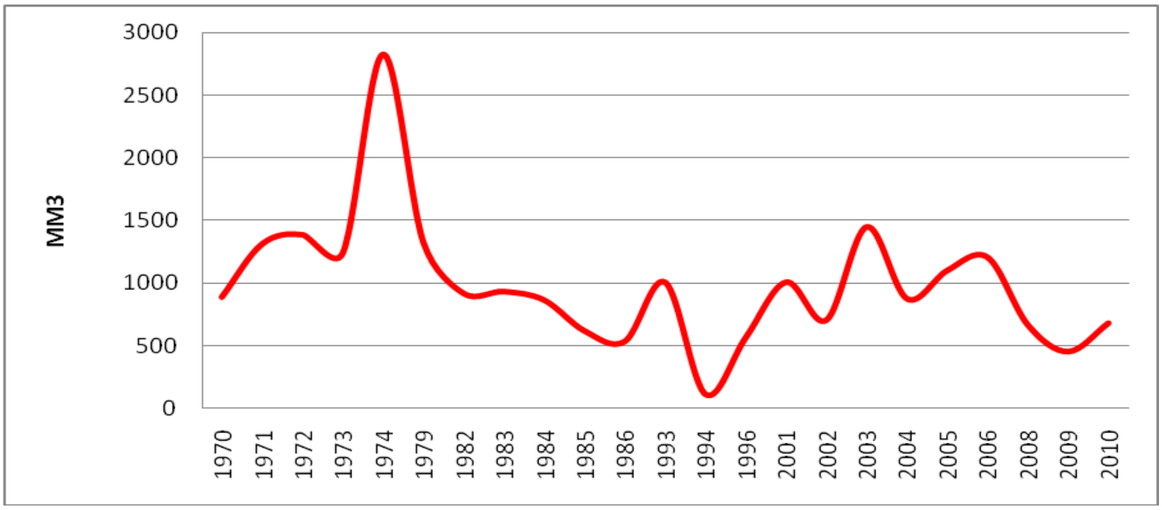


Figure 8: Gash annual flow

However, excessive uses and over abstraction of groundwater rendered the future picture of socio-economic development very dim. As outlined in Drinking Water Authorities reports, Kassala horticultural area located in the most potential zone of the aquifer and is consuming high water quantity. About 3000 wells were drilled in this area producing about 0.546 million m^3 per day (Figure 9). The current number of wells in this area is three times the number of 1982, as consequence of this intensive pumping water level dropped over the area and some wells were completely dry up.

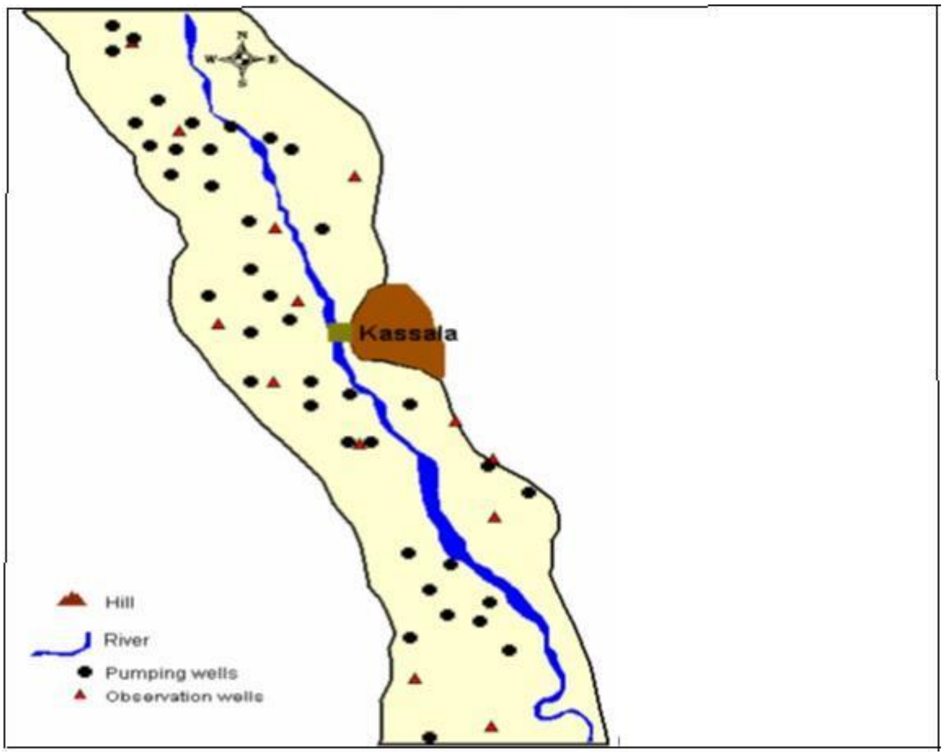


Figure 9: Pumping and observation wells distribution

3.2 Characteristics of groundwater recharge

The River Gash Basin is filled by the Quaternary alluvial deposits, uncomfortably overlying the basement rocks. The alluvial deposits are composed mainly of unconsolidated layers of gravel, sand, silt, and clays. The aquifer is unconfined and is laterally bounded by the impermeable Neogene clays (Figure 10). The average annual discharge of the River Gash is estimated to be 1,056×10^6 m^3 at El Gera gage station (upstream) and 587×10^6 m^3 at Salam-Alikum gage station (downstream). The annual loss mounts up to 40% of the total discharge. The water loss is attributed to infiltration and evapotranspiration. The monitoring of groundwater level measurements indicates that the water table rises during the rainy season by 9 m in the upstream and 6 m in the midstream areas. The storage capacity of the upper and middle parts of the River Gash Basin is calculated as 502×10^6 m^3. The groundwater input reach 386.11×10^6 m^3/year, while the groundwater output is calculated as 365.98×10^6 m^3/year. The estimated difference between the input and output water quantities in the upper and middle parts of the River Gash Basin demonstrates a positive groundwater budget by about 20×10^6 m^3/year (Elsheikh et al, 2011).

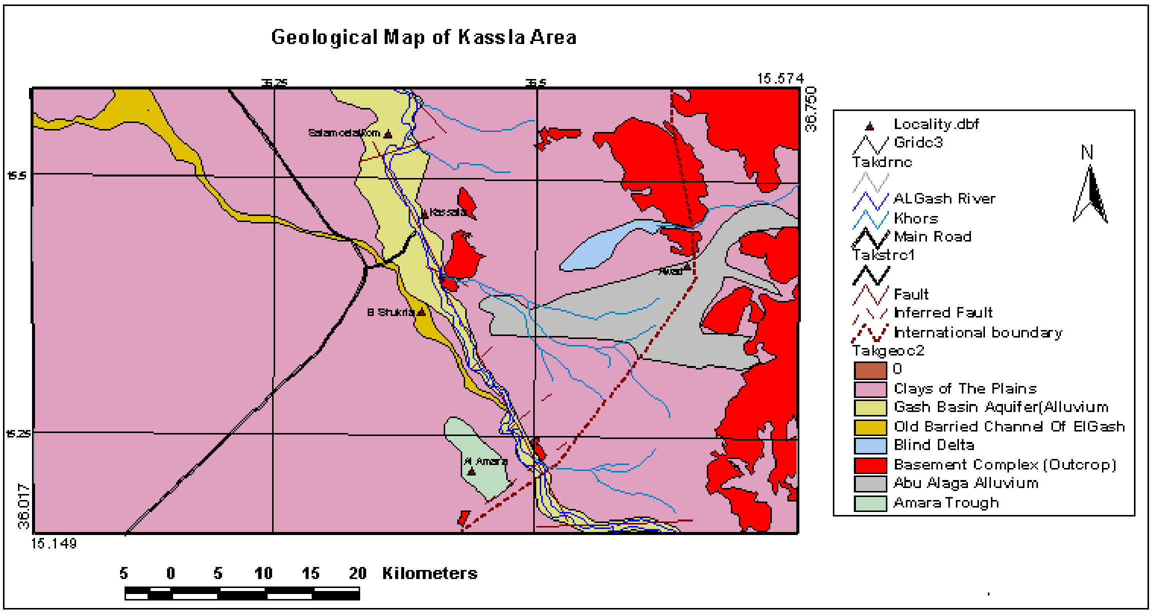


Figure 10: Geological map of Kassala

3.3 Groundwater recharge

The annual runoff range from 2828- 889 Mm^3 during period of 1970-1980, and declined on the last ten years from 1449 Mm^3 to 452 Mm^3. The average annual groundwater recharge in upper sub-basin (from the Sudanese-Eritrean border to Jamam) is about 175 Mm^3, and the rate of recharge around Kassala area is 110 Mm^3. The aquifer is recharged seasonally from the Gash River during rainy season by influent seepage and from direct precipitation over the basin. The ground water is of an excellent quality for irrigation and domestic purposes (Figure 11). The time series hydrographs reflect pattern of groundwater recharge from 2000 to 2010 and recharge-runoff relationship (Figure 12) that shows a general trend of decline and fluctuation in recharge.

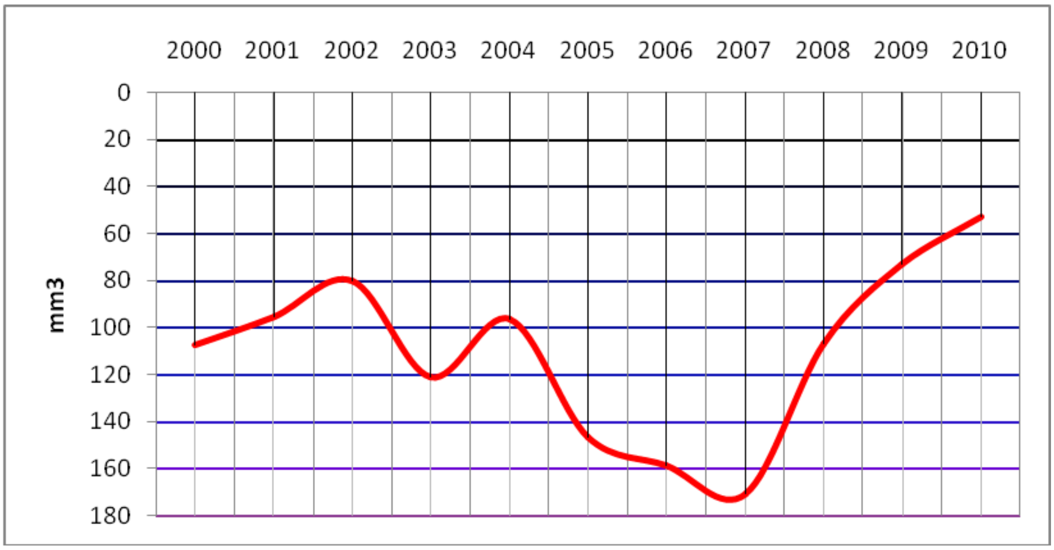


Figure 11: Groundwater recharge in Gash

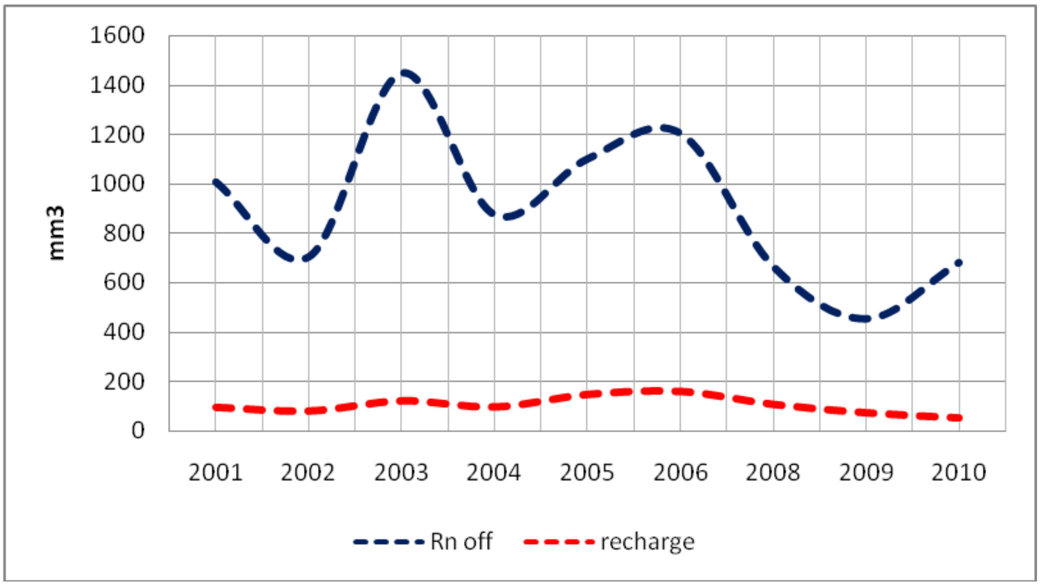


Figure 12: Runoff-recharge relationship in Gash

4. Positive/negative impacts of Mesquite in Gash area

Mesquite introduced in Sudan to protect vulnerable lands and soils and accordingly to help curb desertification (Figure 13). It has occupied fertile land, agricultural area, watercourses, floodplains and highways (Figure 14). The risky point of Mesquite is that it is truly tropical in their requirements and has a low tolerance for temperatures below zero degrees Celsius. Mesquite introduced in Sudan in 1917. Since that time, mesquite spread to cover the whole country (Table 3). Invasion of Mesquite was estimated at 73 percent of total agricultural lands. Mesquite characterized by the deep root system which supports the tree and brings up groundwater to the tree, while the lateral roots collect rain and other surface water as well as nutrients just below the soil surface. The Mesquite flowers are hermaphroditic and insect-pollinated. The flower and fruit production constitute important forage for the livestock during the critical dry season (Figure 15).

Figure 13: Mesquite curbing desertification

Figure 14: Mesquite occupy watercourses, floodplains and highways

Table 3: History of Mesquite in Sudan

Year	Mesquite invasion	Reference
1917	Mesquite introduced in Sudan from Egypt and South Africa.	(Hiroshi, 2012)
1928-1938	Mesquite was introduced in all the country.	(Talaat 2014)
1965	Mesquite was planted in a green belt around Kassala.	(Hiroshi 2012)
1970s	Mesquite seeds were distributed by airplanes in around Kassala and further planted in protected forests.	(Elsidig et al., 1998)
1980s	The tree was planted as shelterbelts.	Ministry of Agriculture
2000s	Mesquite has become a harmful tree in Sudan.	Various references

Figure 15: Mesquite uses as forage for the livestock

4.1 Mesquite adapts various climate conditions

The tree has proven itself to adapt various climate conditions. Regarding the water requirements Mesquite has a wide range of tolerance. It extends from areas with an annual rainfall of only 50 mm to high-rainfall areas with over 1,500 mm of precipitation. The average optimum temperature for Mesquite is from 20–32 ^{o}C, but the whole temperature range is from about 1.5 to over 50 ^{o}C (Hiroshi 2012). There is a strong correlation between phosphorus and nitrogen contents in the soil and those in Mesquite leaves. In case the above-ground part is destroyed, or cutting, there are dormant buds some 10–15 cm under the ground surface from which the tree can sprout again. The high coppicing ability of Mesquite ensures recovery of the plant when it cut and often results in a multi stem tree.

4.2 Spread of Mesquite

Currently the bulk of mesquite infestation found in eastern Sudan where livestock keeping and subsistence cultivation constitute the main source of income. The plant is found in the Gash delta from Kassala northwards passing Wager and southwards up to the borders with Eritrea, in Atbara River, a long Khor Baraka extending from the delta up to 130 kilometres upstream and in water collection pits a long Kassala (Babiker and Nagat, 2007). An increase in rate of spread (371 hectares per annum) was observed during 1978-1992. In 1992-1996 the average rate of spread increased to 460 hectares per annum (Elsidig, 1998). Goats, sheep, cows and feral animals, eat ripened pods and liberate the seeds which are spread into new sites over long distances. The pods are also transported by floodwaters and run-off. The rapidly growing root system and un-palatability of the foliage increase seedling survival rate and competitiveness particularly in heavy grazed areas and/or on uncultivated fallows (Mohamed, 2001). Areas, occupied with Mesquite, are showing an increasing trend while other agricultural areas are decreasing (Figure 16).

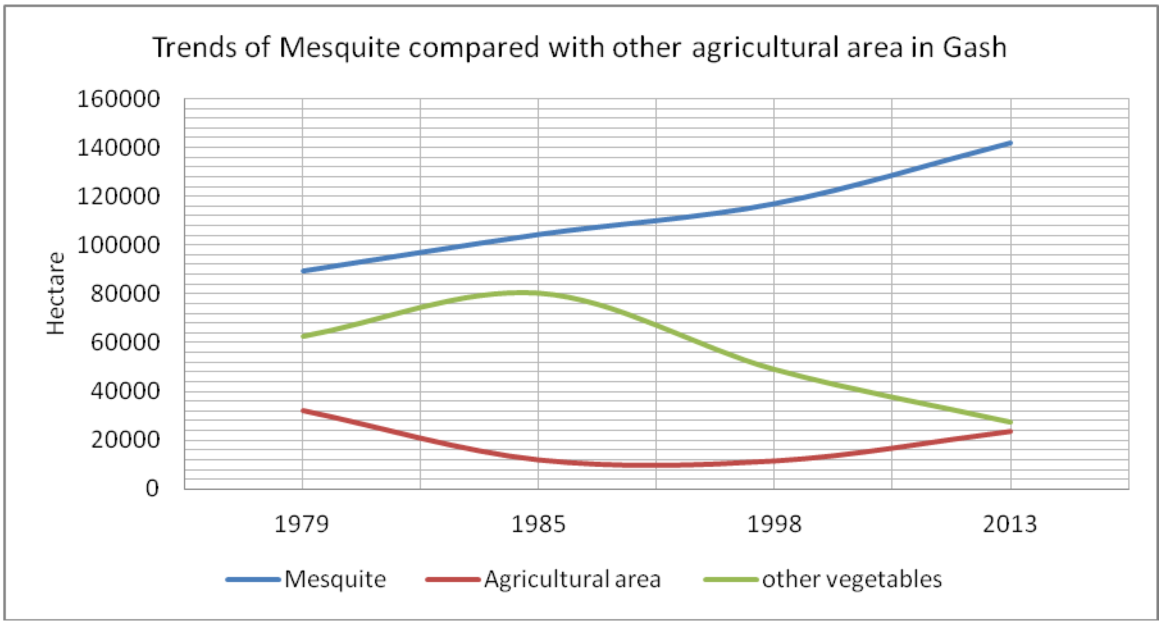


Figure 16: Trends of Mesquite compared with other agricultural area in Gash

Table 4: Positive impact of Mesquite

Positive impact	Clarification
Combating desertification	In Sudan mesquite has been useful in combating desertification by stopping the sand encroachment on sandy soils zones.
Sources of food, feed and energy	It uses as food, feed, fuel and building materials. Mesquite pods, which are high in sugar (30%), with moderate levels of protein (12%), have been used for human and animal food by indigenous people.
Source of income	Mesquite improves the lives, economies, and ecosystems of some poorest people in Gash. As it has an economic importance as the primary source of cash income, particularly for the landless tenants.
Soil improvement	Mesquite is able to improve the soil by means of biological nitrogen fixation, leaf litter accumulation, nutrient pumping from deeper soil layers, loosening of a hard soil structure, stabilizing of loose sands. The Mesquite increases the amount of soil organic matter in the soil directly and thereby positively influences the potential of the soil to absorb soil moisture, which leads to sustainable soil fertility.
Mesquite wood	The wood has durability, strength and hard compared with other trees (Hiroshi, 2012). Mesquite is also an important source of household energy for millions of people in Gash area. 70% of charcoal used in Gash is from Mesquite and the remaining 30% is from other trees (Talaat, 2014). Records of commercial production of charcoal and firewood in 1996/97 from Gash and Atbara rivers were 600,000 sacks and 135,000 m^3, respectively (Elsidig et al., 1998).
Mesquite pods	Mesquite produces abundant quantities of often sweet fruit pods. Industrial processing of the pods can produce seed gums for use as a thickening agent in food preparation, dietary fibre and ethanol as a bio fuel. Mesquite pods are used in Sudan mainly for livestock fodder. Honey produced is of the highest quality.

Table 5: Negative impact of Mesquite

Negative impact	Clarification
High water consumption	Mesquite is considered aggressive invasive shrub along the Gash riverbanks and over flood plain on areas that are public lands or under-utilised, especially on well drained soils where its root system can reach the water table. Because of its extensive root system it also provides a degree of stabilization where it has colonised the river bank levees.
Invasiveness trees	The tree, as an alien invasive species, is a noxious weed in agricultural areas. It is regarded as one of the worst weeds in such areas because of its invasiveness, potential for spread, and economic and environmental impacts. Mesquite is competing other plants.
Invader of farmlands and watercourses	Mesquite has become a formidable invader of farmlands and watercourses, floodplains, highways, degraded lands, abandoned lands irrigated areas, ponds, rivers, lakes and swamps.
Hard thorns	Thorns 70-100 mm long grow along the tendrils and inflict injury to people and animals and cause punctures tyres.
Adverse environmental impacts	Adverse environmental impacts include land erosion resulting from the loss of grassland habitat that supports native plants and shrubs that are better-suited and more productive for local growing conditions (for cropping/livestock and for native flora and fauna).

5. Impact of upstream activities on downstream FBA (Gash die)

In flood systems, activities that occur in upstream may have a direct influence downstream from a few to many thousands of kilometers away. It is particularly critical in floods like Gash, where the climatic and geological conditions at the source of the river in Ethiopian high lands are completely different to those downstream, where activities in one place may directly impact the situation in another. Upstream impacts on downstream flood based activities can be broadly divided into two types: human-influenced activities related to land use and natural impacts related to climate. Flood management practices in upstream can have both beneficial and adverse effects on downstream communities. Good flood management practices upstream can provide better opportunities for downstream communities. In contrast, poor management practices may not only degrade upstream environmental conditions, but will also limit the opportunities downstream. Upstream activities such as flood control, irrigation, and domestic water supply which can influence the downstream flow in many ways (including timing and frequency). Gash flood is important for irrigation of farmland in the Gash Irrigation Scheme, refilling haffirs, recharging groundwater and supplying water to rangeland and natural forests in the Gash Die area. Historical observation shows changing and more erratic behaviour of the Gash River. The flood patterns and floodwater discharge (average 680 million m^3 per year) is changing due to climate change and increasing water use upstream. The sediments (5.5 million m^3 per year) are increasing due to deforestation in catchment area upstream.

5.1 Impact of extensive land use upstream

The vegetation cover reducing soil erosion in upstream and thereby expected to reduce sediment load in flood plain areas downstream. Walling (1999) stated that a change in surface condition from natural undisturbed land to cultivation will in general result in an increase in the soil erosion rate. For Gash case it seems that the upstream users have the absolute priority right on base flow in accordance with the traditional rules. So, upstream farmers got ahead with more reliability irrigation that encouraged them to change the cropping patterns from cereal crops into horticultural crops which require water all year round. This shift in cropping pattern has improved the living standard of farmers, but it has mainly focused on the upstream region of the scheme and has led to reduced spate flows to the downstream area and thus has deprived the tail-end (Gash Die) farmers of their livelihood.

5.2 Expansion of horticultural production upstream and its impact downstream

The Gash flood uses for (39%) for irrigation, 28% for recharging ground water and 33% for grazing land and natural forests in the Gash Die. Expanding of cultivable land has a significant impact on the amount of water supplied downstream to Gash Die (Figure 17). In fact horticulture is supported by groundwater wells and as a result, the area under horticultural crops has increased in upstream area. In the Gash flood plain in Sudan, groundwater from shallow wells is used for the cultivation of horticultural crops (bananas, onions and other fruits), Figure 18. Fruits have become the foundation of the economy and then have generated a significant demand for wage labor (Frank et al., 2010). Sometimes the upstream users captured the spates to irrigate their fields and therefore depriving the downstream area from the spates gradually. Capturing the floodwater in upstream will minimize possibility recharging of groundwater aquifer especially to down streamers. It has been observed that Gash Die suffered drinking water shortage most of the year.

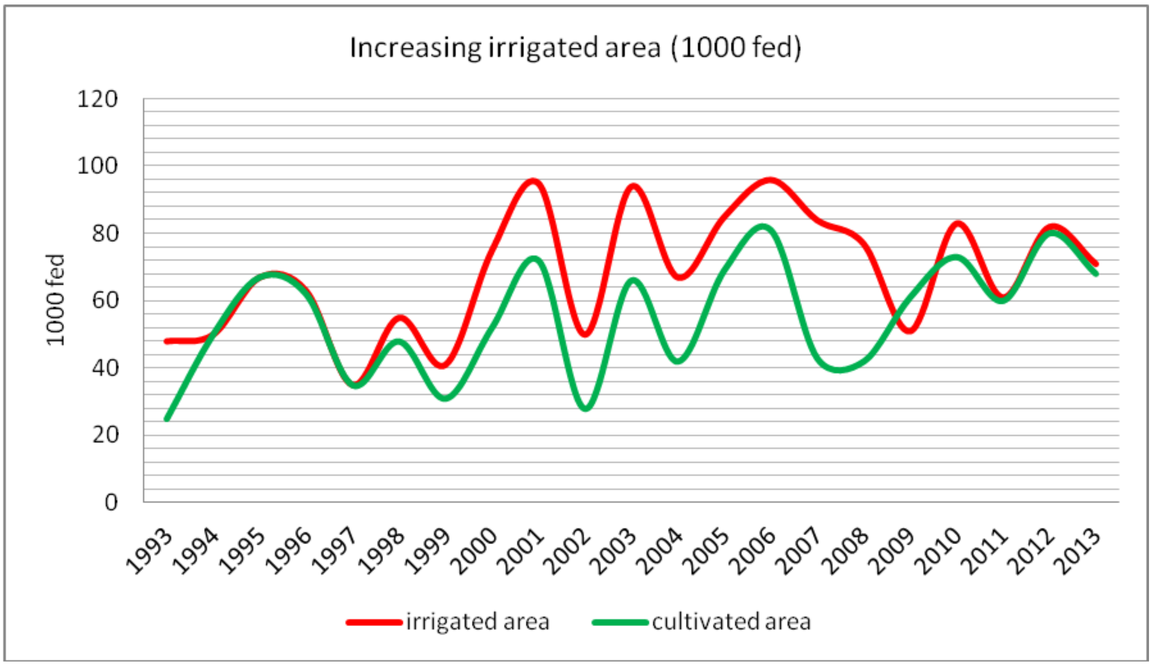


Figure 17: Increasing irrigated area in Gash

Figure 18: Horticultural crops (bananas and other fruits) supported by groundwater

Table 6: Upstream activities impacted downstream FBA

Upstream activities	Upstream	Adverse impact
Vegetation cover change	- Reduce soil erosion	- Reduce sediment load in flood plain
Expansion of horticultural production	- High water consumption - Improve livelihoods of up-streamers	- Low groundwater recharge, low flood, small irrigated area, reduction of grazing area - Problems of drinking water

New structures (Dykes)	- The city protection - Narrowing the river course and reduces the flood time to recharge groundwater - High velocity created	- Flushes more sediment downstream - Reduction of irrigated areas downstream

6. Ecosystems benefits in GAS under various development scenarios

An ecosystem is a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit. Examples of ecosystems include deserts, wetlands, rainforests, grasslands, and cultivated farmlands. People obtain a lot from ecosystems. Examples include food, freshwater, timber, climate regulation, protection from natural hazards, erosion control, pharmaceutical ingredients and recreation. Biodiversity is the quantity and variability among living organisms within species (genetic diversity), between species and between ecosystems. Ecosystem benefits are integral part of development. Human societies derive many essential goods from natural ecosystems, including food, animals, fodder, fuel wood and pharmaceutical products (Table 7). These goods represent important and familiar parts of the economy.

An ecosystem is essential and dynamic "factors of production" for social and economic development. The well being of human society is based on ecosystems which produce the bulk of both renewable resources and ecosystem services. Gash community came into being after most ecosystem services had been in operation for hundreds of years. The human economy depends upon the services performed for free by ecosystems. The resources in Gash create ecosystem processes that include various species of animals, different type of foods: the biological, chemical, and physical interactions between components of an ecosystem (e.g., soil, water, and species). These processes produce benefits to people in the form of water, land, and reductions in erosion, among others. Food such as animal meals, egg milk, sorghum, vegetables, onion and fruits are of vital important for human life. Fresh water (ground water recharge) and mineral resources (clay and sand soils) are essential. Also animal skins are being used as inputs in the manufacturing of leather and leather products.

Forests, grasslands, freshwater, and other natural ecosystems provide a range of services that are not recognized in economic accounting systems, but are vital to human welfare, including water flow and water quality regulation, flood control, pollination, decontamination, carbon sequestration, soil conservation, nutrient and hydrological cycling. Ecosystems benefits in Gash can be investigated under various development scenarios such as agriculture, livestock, water resources and human development scenarios (Figure 19).

Table 7: Ecosystem benefits

Source	Benefits
Food	Gash ecosystems provide the conditions for growing food. Food comes principally from Gash river flood which is the main source of water. Growing sorghum fruits and vegetables.
Energy	*Mesquite* charcoal which is used for cooking. Gash community prefers mesquite

	as source of energy because it burns hot. The charcoal sector has acquired considerable economic weight as it used in food and traditional coffee making in Gash.
Raw materials	Ecosystems provide a great diversity of raw materials for construction and fuel including Mesquite wood and plant oils that are directly derived from forest and cultivated plant species.
Fresh water	Gash river play a vital role in the hydrological cycle, as it provide Gash area with water for drinking, agriculture and other purposes.
Medicinal resources	Ecosystems and biodiversity provide many plants used as traditional medicines as well as providing the raw materials for the pharmaceutical industry.
Erosion and soil fertility	Gash river renew soil regularly and soil is non-degradable in Gash flood plain. Soil fertility is essential for plant growth and agriculture and well functioning ecosystems supply the soil with nutrients required to support plant growth and vegetation cover which is preventing soil erosion.
Pollination	There are many types of insects in Gash. Insects and wind pollinate plants and trees which is essential for the development of fruits, vegetables and seeds. Animal pollination is an ecosystem service mainly provided by insects but also by some birds.
Recreation	Walking and sitting near Gash is not only a good form of physical exercise but also keeps people relax.
Tourism	Gash considered the tourist place in Sudan. There are Gash hills *(Totel) and Margania*. Most of Sudanese Newlyweds spend the honeymoon in Gash to visit the tourists' places. Ecosystems and biodiversity play an important role for many kinds of tourism which in turn provides considerable economic benefits and is a vital source of income for Gash.

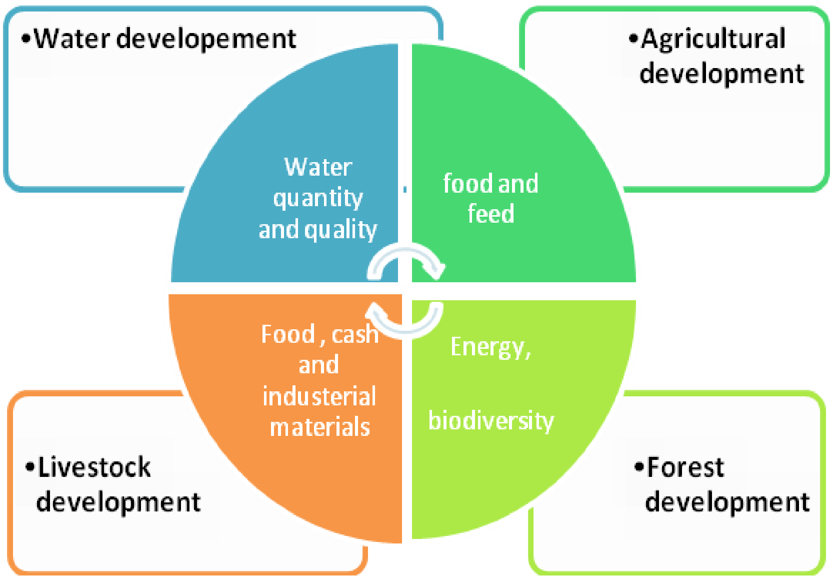


Figure 19: Ecosystem benefits under various development scenarios

7. Ecosystems and landscape perspective to current/planned interventions and policies

The physical appearance of the land surface in Gash include scales ranging from populations to landscapes which involve open forests, grasslands, Gash River and fragmented villages. Land is used for plantations of vegetables, fruits, crop agriculture, pastures and human settlements (Figure 20). The current process of land use and land management practices considered ecosystem necessary for organisms and natural processes. However continue transforming land to provide food and products will affects many of the physical, chemical, and biological systems and directly impacts the ability of ecosystem to continue providing the goods and services upon which humans depend. Current interventions and policies in Gash include farmers' participation through water users associations, practices of water harvesting, control of Gash River flood. Future polices include agricultural mechanization, eradication of Mesquite, introduction of new crops and increase of agricultural area and productivity.

Gash has fertile soil with good physical properties to support root growth which is essential for sustainable agriculture. The agricultural systems in Gash indicate the value of using the landscape in a way consistent with sustainable ecosystem function. Location of agricultural areas across the landscape will take advantage of local variation in water availability and soils. For instance, crops are planted to cover the whole flood plains consuming seasonal flood and rainfall. These areas of the landscape received regular inputs of silt as well as water through Gash River. Planting during wet season in Gash improves the supply of ecosystem services like soil quality, habitats and weed control. The current policy of agriculture in Gash is to raise productivity of sorghum, however still agricultural practices are poorly managed. Farmers prefer intensification of crops and this will support supply of ecosystem services. Farmers' participation in water and land management influences soil fertility and change. Continious producing heavy vegetables and fruits in Gash will be costly when viewed from long-term and broad-scale perspectives. For example, growing consumptive crops (Banana) in arid areas is possible, but draws down groundwater at a rate unsustainable by natural recharge. In Gash systems, land-use and land-management practices can lead to soil improvement and enhance the long-term potential productivity and can help species composition.

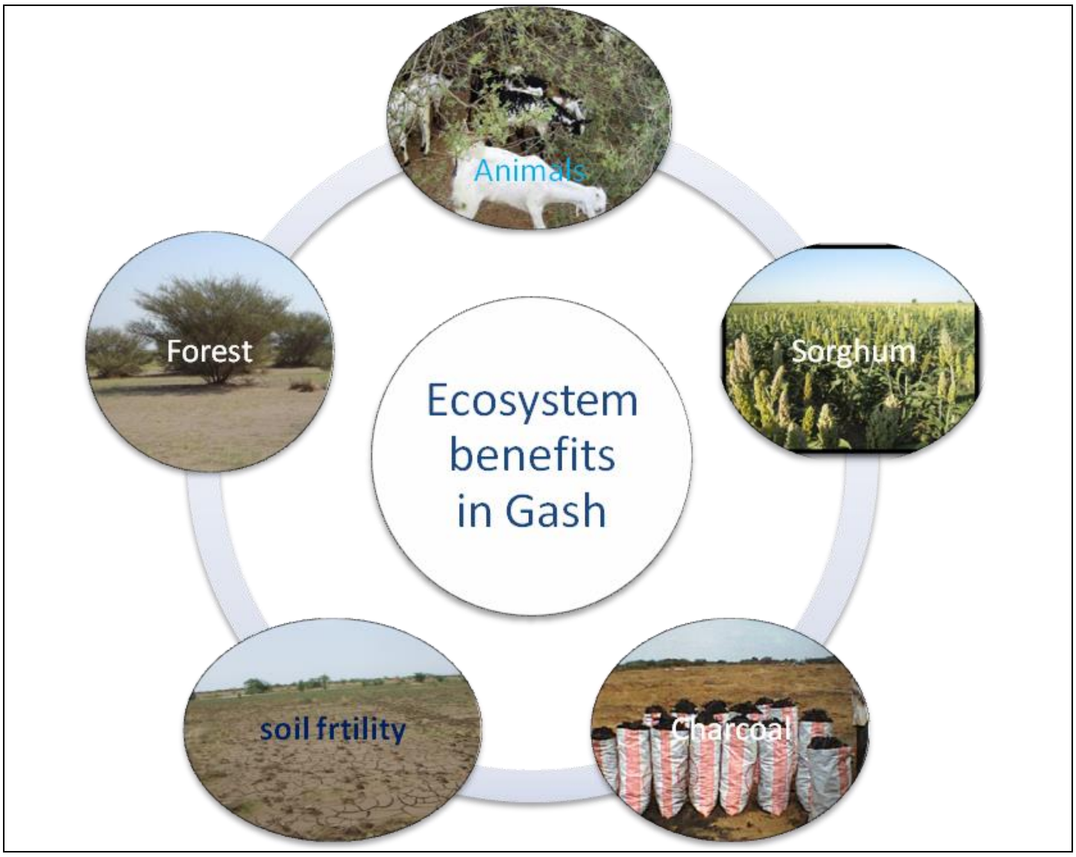


Figure 20: Ecosystem services and benefits linkages

7.1 Ecosystem benefits evaluation

This valuation does not assess the full range of ecosystem services but focus on just a few services. Not all biodiversity values can be reliably estimated because of shortage of data. This method used the below schematic diagram to identify all ecosystem services and benefits and then put determined values (Figure 21). The estimated ecosystem value in Gash is about 33 million USD (Figure 22). Values such as education, health, settlement and culture considered non-use value and not estimated. Land is extensively used in Gash and therefore, ecosystem value expected to be low as there is inverse relationship between land use and ecosystem value as shown in Figure 23.

Table 8 gives a quick overview on the winners and losers in Gash River basin based on different proposed development scenarios.

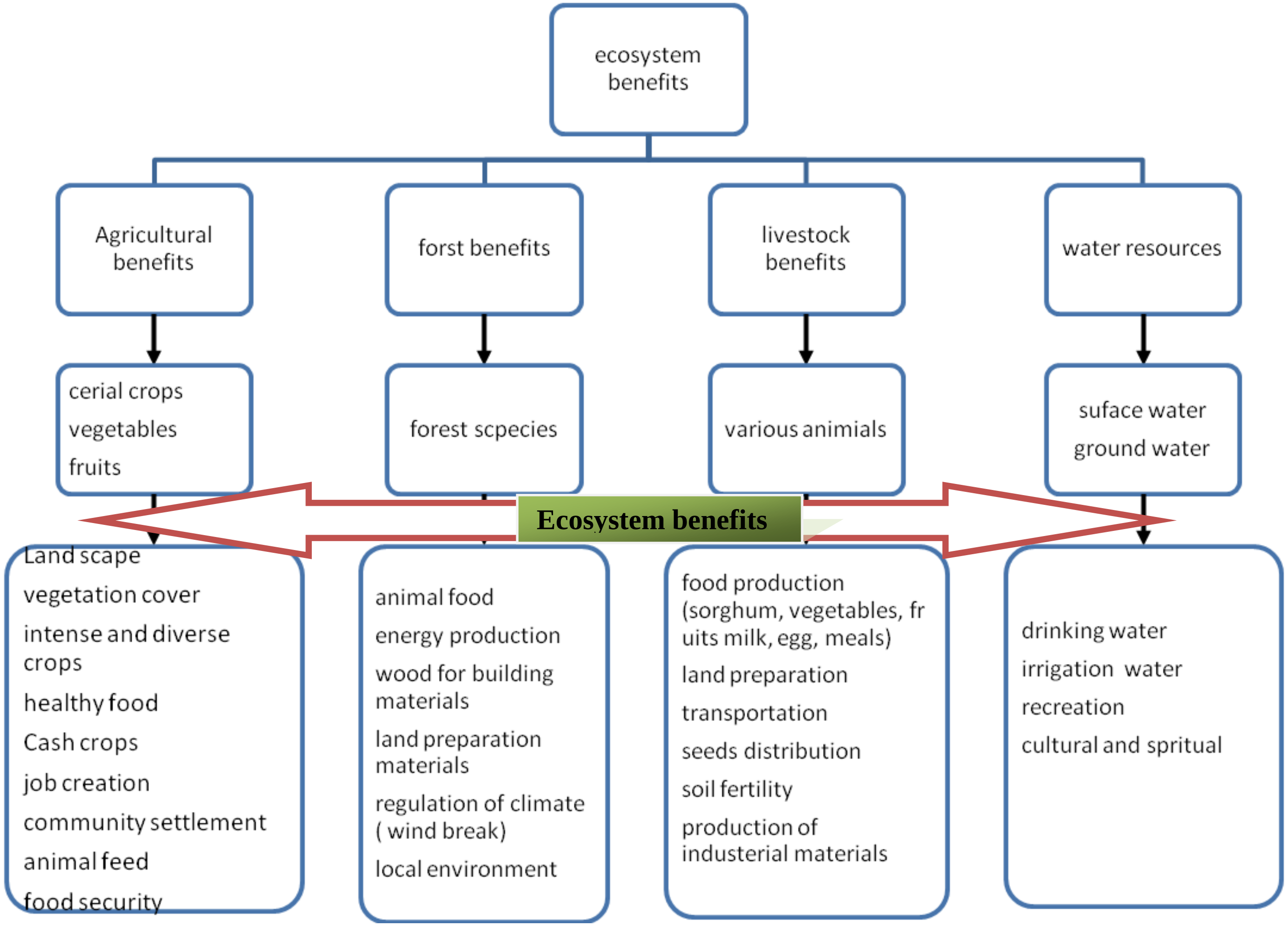
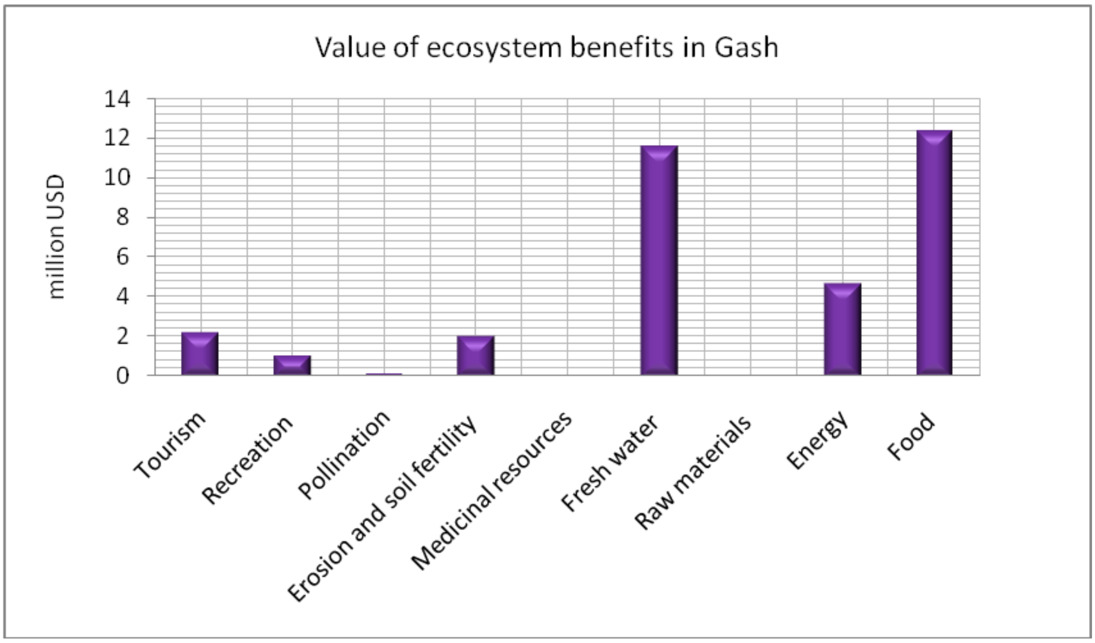


Figure 21: Schematic diagram for ecosystem benefits in Gash



Source: Estimated by Eltigani Bashier in consultation with other economists

Figure 22: Valuation of ecosystem benefits in Gash

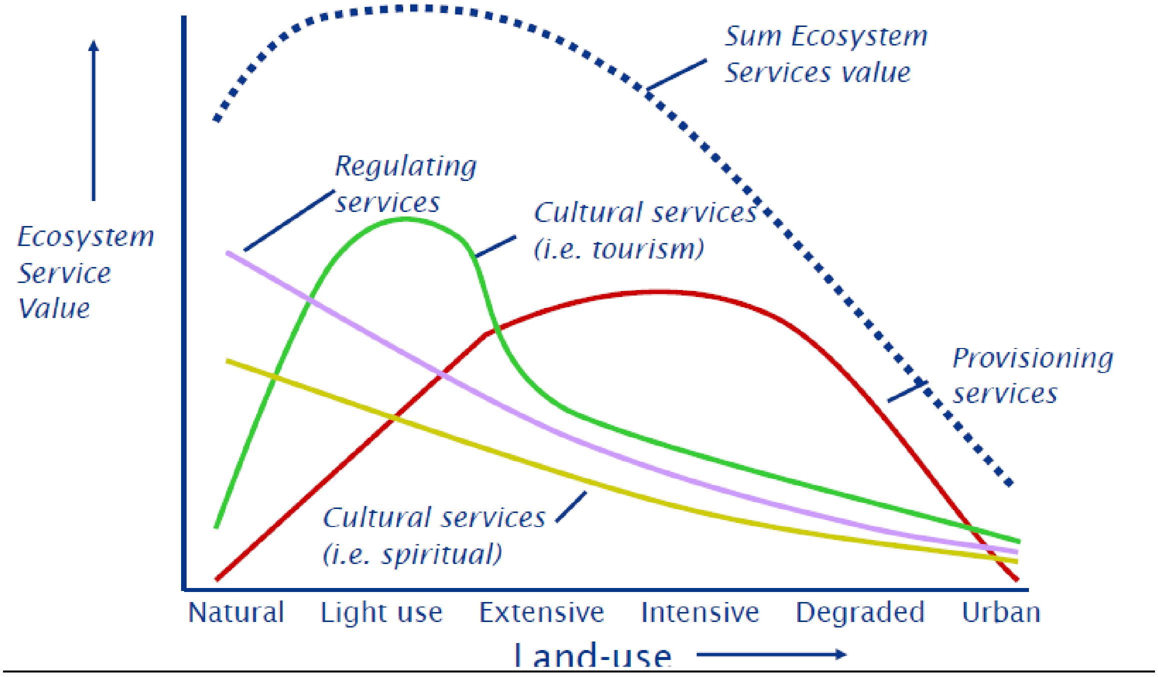


Figure 23: Relationship between land use and ecosystem services

Table 8: Winners and losers

Winners	**Losers**	**Why?**
Livestock	Forest and other plants	Deforestation and heavy grazing
Agricultural sector	Groundwater recharge	Expansion of agricultural land consumes a lot of water left few percentage of water to recharge
Soil	Water supply	Sedimentation renew the soil
Up-streamers	Down streamers Gash Die	Up streamers uses most of water and reduces the amount of water downstream

8. Summary

Gash is the only major source of water: Investment in one of the benefit streams, without analysing implications on the others, will not lead to optimal use of Gash river flow. Next to agriculture and horticulture, there are many more benefit streams that have received little attention (forests, grazing land, tourism, etc.). IWRM approach is required for developing interventions that result in equitable, efficient and sustainable use of Gash River flow.

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