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## Ecosystem management is the key to reduce climate impacts and food security

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### Abstract

Ecosystems provide food to all organisms living there. To secure energy and nutrients, healthy and functional ecosystems are required. Most of the ecosystems are vulnerable to anthropogenic activities and climate change and have lost their productivity. The hydrological cycle has been obstructed due to deforestation, construction of dams and embankments, unplanned infrastructures, and agricultural expansion, and thus food security is under threat. So, it is urgently needed to restore healthy and functional ecosystems. Some practices are mentioned in this paper for ecosystem-based adaptation, among them traditional flood plain management and rural home-centered aggregated farming are important.

**Keywords:** Ecosystem, food security, landscape management, water cycle, global warming, climate smart agriculture, ecosystem-based adaptation

### Introduction

An ecosystem includes all of the living things *viz.* plants, animals, and microbes in a given area that interact with each other, as well as the non-living environments like weather, earth, sun, soil, climate, atmosphere that surround the living things. The main function of ecosystem is to transfer of energy into living system and conversion of biomass utilizing nutrients from the soil, water and air. This biomass production, transfer and recycling is the overall food system (Ricard, 2014) [66]. The productivity of an ecosystem depends on geographical position, landscape, climatic factors and availability of soil and water along with the biotic components. Different ecosystems transform energy into organic matter; the ecosystems are distinguished from one another by their productivity. The greatest production yielded by forests, savannah, steppe and cultivated land. Primary production on land is about twice than the ocean (Table 1) and there is a regular reduction in ecosystem productivity as one moves from the tropics to the Polar Regions (Astanin and Blagosklonov, 1978) [6].

**Table 1:** Net primary production of the biosphere and its ecosystem

Land/Ocean	Ecosystems	Area million km <sup>2</sup>	World production Billion tons/year
1	Rivers and Lakes	2	1.0
2	Swamps and Marshland	2	4.0
3	Tropical Forests	20	40.0
4	Temperate Forests	18	23.4
5	Northern Forests	12	9.6
6	Arid Forests	7	4.2
7	Savannah	15	10.5
8	Steppe	9	4.5
9	Tundra	8	1.1
10	Semi-desert	18	1.3
11	Desert, Rock, Ice	24	0.07
12	Cultivated Land	14	9.1
	All land	149	109.0
13	Oceans	332	41.5
14	The Shelf Zone	27	9.5
15	Estuaries and Algae	2	4.0
	World Ocean	361	55.0
	The Whole Biosphere	510	164.0

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Source: Astanin and Blagosklonov, 1978 [6]

During the processes of ecological systems, it provides benefits to humans and is termed as ecosystem services (ODI, 2015). With the advancement of agriculture, urbanization and industrialization human involved in the regulation of the production system to harness the benefits and thus managing the ecosystems. Much progress has been made in reducing hunger and poverty and improving food security and nutrition. But major concerns persist; some 795 million people still suffer from hunger and more than two billion from micronutrient deficiencies or forms of over nourishment. In addition, global food security could be in jeopardy, due to mounting pressures on natural resources and to climate change, both of which threaten the sustainability of food systems at large (FAO, 2017) [27]. Still, there are many ecological systems are beyond the control of human being but many systems are over-explored and highly-intervened. The well-being of people all over the world depends on healthy ecosystems to provide goods, like food and water, and services like climate regulation and protection from natural hazards (WHO, 2019) [79].

### Global Population and Food

According to United Nations World Population 2017 estimate, the global population has increased from 2.536 billion to 7.383 billion during the period 1950 to 2019 and it will be 9.314 billion in 2050 and 10.301 billion in 2100. Physical factors that affect population distribution include altitude and latitude, relief, climate, soils, vegetation, water and location of mineral and energy resources. Of all the geographic influences on population distribution, climatic conditions are perhaps the most important. Climate affects population distribution both directly as well as indirectly through its effects on soil, vegetation and agriculture that have direct bearings on the pattern of population distribution (Joshi and Maharjan, 2013). The fertile alluvial and deltaic soils can support dense populations and the major concentrations of populations in the world are located in the river valleys and deltas. Similarly, the chernozems of steppe grasslands and rich volcanic soils can support dense population. Moreover, application of modern technologies during the recent times has greatly enhanced the profitability of cultivation in many areas of the world, which were hitherto not suitable for cultivation (Jones *et al.*, 2017) [38].

In association with climatic conditions, varying soil types give rise to variety of vegetation cover on the earth surface and provide contrasting environment for a variety of agricultural activities, and hence, lead to different population density. Tropical forests, savanna, tundra and taiga provide different media for human occupation and concentration (Clarke, 1972) [79].

Food is the nutritious substance for living organisms like human, animals, plants and microbes which provide energy and nutrients for survival. The ultimate source of energy is the sun; the nutrients get from the soil, water and air (Fernando, 2012; Singh and Schulze, 2015). The nutrients make the body components; conduct metabolisms, interact and transfer energy through food chain and food web. Thus food is the linking composition of energy and nutrients for the population as a whole. Availability of light, air, water, soil and interaction of biotic and abiotic components are essential for ensuring food production and supply.

### Food Insecurity in Changing Climate

With the beginning of agriculture human domesticated certain plants and animals mainly for their food. The domesticated

plants are the crops, primarily for food production. Climate is the basis for crop production as climate determines crop adaptation; eventually the weather in the locality determines the crop development and productivity. Photosynthesis is the single most important process that is responsible for crop productivity, depends on light, temperature, carbon dioxide and water (Acquaah, 2002) [1]. The food systems on which food security depends are subject to risks of various natures. These risks can impact directly the four dimensions of food security and nutrition: agricultural production, access to food, utilization, and stability. They include climatic risks themselves and, as shown above, many other risks that are, in turn, influenced by climate change, or that may combine with climate change induced risks and have compensative, cumulative or amplifying effects. The net impact of a climatic shock on food security depends not only on the intensity of the shock but also on the vulnerability of the food system to the particular shock, i.e. the propensity or predisposition of the system to be adversely affected (IPCC, 2012). With the increased population human faces insecure to sufficient amounts of safe and nutritious food for normal growth and development and an active and healthy life. Food security vulnerability due to climate change is the propensity of the food system to be unable to deliver food security outcomes under climate change (FAO, 2016) [26].

Anthropogenic climate change is widely regarded as one of the most significant threats to global food security, impacting all dimensions of food production, availability, stability and utilisation (Schmidhuber and Tubiello, 2007; Wheeler and Von Braun, 2013; Gbegbelegbe *et al.*, 2014; Tai *et al.*, 2014) [67, 78, 29]. For example, climate change has been shown to directly impact food production through changes in agro-ecological conditions, with declines in food production and increasing variability of food supply already attributed to observe warming and changes in regional rainfall patterns (e.g. Parry *et al.*, 2004, 2005; Fischer *et al.*, 2005) [55-56, 28]. Climate change also affects the ability of individuals to access and use food effectively by altering the conditions for food safety and increasing the risks of vector-, water- and food-borne diseases (Githeko *et al.*, 2000; Patz *et al.*, 2005) [32, 57]. As a result, it has been projected that the number of undernourished people may increase by up to 26% by 2080 (Fischer *et al.*, 2005) [28]. Consequently, achieving food security under the changing climate is a critical public policy problem, particularly given the tendency of climate change to interact with other economic, political, temporal and biophysical drivers (Ericksen *et al.*, 2009) [19].

Climate change will affect the agricultural sectors in many ways, and these impacts will vary from region to region. For example, climate change is expected to increase temperature and precipitation variability, reduce the predictability of seasonal weather patterns and increase the frequency and intensity of severe weather events, such as floods, cyclones and hurricanes. Some regions are expected to face prolonged drought and water shortages. The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (IPCC, 2014) also points out that changes in climate and carbon dioxide concentrations will enhance the distribution and increase the competitiveness of important invasive weeds. As a result of climate change, some cultivated areas may become unsuitable for crop production, and some tropical grasslands may become more arid. According to Ray *et al.*, 2019 climate change has already affected global food production.

### Landscape Management is the Key to Ensure Healthy Ecosystem

Landscape management is an integral part of natural conservation vis-à-vis proper land utilization for production of food and other essentials managing the land resources like water, soil and biodiversity. It requires collective ideas, compromising the need of existence of all, fulfillments of the needs of human beings and long-term foreseeability to assess any detrimental effects by manmade activities directly or indirectly. Learning to measure how landscapes perform in delivering food, biodiversity and livelihood outcomes is anticipated to endow management systems with the capacity to sustain these multiple functions while reducing or reversing the degradation of natural resources.

However, lack of understanding or feelings of ill competition for existence or dominance, human beings are often biased with natural resources; quick manmade change of landscape is one of them. Therefore, to secure the lives and livelihoods, it needs to manage natural systems wisely and logically to conserve and maintain the significant features of a landscape, which is greatly valued on account of its distinctive natural or cultural configuration. Such protection must be active and involve management measures for preservation of significance. For framing proper planning, more particularly in those most affected by change and badly damaged areas like suburbs, peri-urban and industrial areas, floodplains and coastal areas, there needs a systematic study on overall changes due to steadfast increase of population and significant industrialization during the last century (Rahman *et al.*, 2018) <sup>[62]</sup>.

#### **Disruption of the Water Cycle and River Ecosystems**

Loss of forest disrupts water cycle, resulting in less rainfall and causing drier conditions over broad surrounding areas, sometimes leading to drought. Forests also retain moisture from rainfall, allowing it to recharge water tables and regulating the flow of water into rivers and other waterways. Loss of forests often results in increased flooding and erosion of sediment into rivers, disrupting river ecosystems (Johnson, 2017).

#### **Global Warming**

Deforestation is a primary cause of human-caused carbon dioxide emissions leading to global warming (IUCN, 2017) <sup>[36]</sup>. Global warming threatens ecosystems and biodiversity globally (Johnson, 2017). Rapid and abrupt land-use changes, mainly due to development pressures and urban sprawl, habitat fragmentation due to transport infrastructures, resource overexploitation and pollution, are few of the main factors impacting upon Mediterranean forests and driving their degradation. Once climate change is added upon those, accompanied by heat-waves, drought and overall temperature rises, the resilience and adaptation capacity of forests is exhausted (WWF and IUCN, 2008) <sup>[85]</sup>. Mediterranean areas have experienced an increase in aridity in the last decades. Warming trends have been registered in the Mediterranean Basin. Precipitation has begun to exhibit either a long-term downward trend, mainly in the dry season, or no significant change although in all cases a rise in potential evapotranspiration has led to increased aridity. In South California and South Africa similar trends have been observed in the recent past and are projected for the coming decades. Drought is the main concern in Mediterranean areas. It negatively affects most services, from food production, by decreasing water sources for irrigation, to carbon-storing capacity (Penuelas *et al.*, 2017). Deforestation and degradation of forests create ecological problems in every part of the world. Deforestation is occurring at a rapid pace, especially in tropical

regions where millions of acres are clear cut every year. Remaining forests also suffer from pollution and selective logging operations that degrade the integrity of local ecosystems. Destruction of forests also effects the soil and water quality in the immediate area and can have an adverse effect on biodiversity over a range of connected ecosystems. Over half of all terrestrial species live in rainforests, which are subject to the greatest deforestation pressures. Biodiversity loss can occur during selective logging as well, as individual species may be intolerant to loss of a particular tree type or to the presence of logging operations (Johnson, 2017) <sup>[37]</sup>.

#### **Impacts of Climate Change on Forests**

Forests are particularly sensitive to climate change, because the long life-span of trees does not allow for rapid adaptation to environmental changes. Adaptation measures for forestry need to be planned well in advance of expected changes in growing conditions because the forests regenerated today will have to cope with the future climate conditions of at least several decades, often even more than 100 years.

Rising atmospheric CO<sub>2</sub> concentration, higher temperatures, changes in precipitation, flooding, drought duration and frequency will have significant effects on trees growth. These climatic changes will also have associated consequences for biotic like outbreaks of pests and diseases and abiotic disturbances like the incidences of fire and storms frequency and intensity with strong implications for forests ecosystems. Reduced stability will decrease the protective function against natural hazards like flooding, debris flow, landslide, and rock fall, while hazardous processes itself might be both intensified or alleviated by the expected climatic changes (EU Report, 2008).

The recent European heat wave broke temperature records at many locations in France, Switzerland, Austria, Germany and Spain. In France it was broken by more than 1.5°C on 28 June, with 45.9°C recorded near the city of Nîmes (Oldenborgh *et al.*, 2019) <sup>[52]</sup>.

#### **Tropical Forest Loss and Climate Change**

According to new University of Maryland and World Resources Institute (WRI) analysis, 2017 tropical deforestation was 39.8 million acres in 2017 and 41.7 million acres in 2016. According to IUCN more than half of the world's tropical forests have been destroyed since the 1960s. The recent study suggesting that deforestation, degradation, and general disturbance have already combined to make tropical forests a net carbon source rather than a sink, meaning they are losing more carbon than they can absorb (NASA, 2017) <sup>[46]</sup>.

Climate change is also contributing to the loss, bringing forests more severe and frequent tropical storms. In 2017, hurricanes destroyed 32 percent of Caribbean island Dominica's forests, according to WRI. Puerto Rico offers another grim preview of what's to come, with storms like Hurricane Maria destroying 50 percent of the canopy last year alone – compared with 1 percent in a typical year. Tropical forest fires, often started by humans to clear land for farming or mining, get worse with climate change impacts like drought and severe heat. In 2017, record-breaking fires ripped through the Brazilian Amazon, the most since monitoring began in 1999. Climate emissions tracked to major disasters serve as an apt illustration of the potential impact of tropical forest loss: Scientists used mapping and modeling data to estimate that the roughly 320 million large trees lost during Hurricane Katrina had been holding 105 tera-grams of carbon, representing 50-140 percent of the net annual U.S. forest tree

carbon sink. Tropical deforestation actively contributes to the vicious cycle of climate change. Scientific modeling, according to WRI, “strongly agrees” that continental-scale deforestation of tropical forests would make those areas warmer and drier. Deforestation in areas like the Amazon, Southeast Asia, and the Congo can also affect the water cycle, with local and global implications (Scholze, 2006 and Simons, 2018) [68].

#### **Degradation of Ecosystem through Agricultural Expansion**

Growing human population and rising per capita consumption lead to ecosystem degradation and biodiversity decline worldwide (Gibbs *et al.*, 2010) [30]. Agricultural expansion for the production of food, feed, fibre and fuel has generated fundamental benefits for human welfare (Godfray, 2010) [33] but comes with a variety of costs (MEA, 2005 and Newbold *et al.*, 2015) [49]. These costs may compromise human well-being in the long term, as they are linked to greenhouse gas emissions, declining biodiversity (Gibson *et al.*, 2011 and Stork *et al.*, 2009) [31, 72] and degradation of a variety of regulatory ecosystem services that affect air quality, purification of water, carbon storage or soil erosion. It is commonly assumed that the conversion of natural to agricultural systems leads to major losses of important ecosystem services. However, the degree to which agricultural systems still provide certain ecosystem services strongly depends on the converted ecosystem, the type of planted crop, the spatial dimensions of plantations, and the management practices in place. With the exception of small-scale experiments, the mechanisms governing the relationship between biodiversity and ecosystem functions remain poorly understood, especially in tropical rainforest ecosystems, which experience massive transformations and varying land use intensities. In tropical Asia, a rapidly growing population and agricultural expansion coincides with one of the highest levels of biodiversity and endemism worldwide. Rainforests in Southeast Asia have been logged on a large scale since the mid 20th century, usually followed by subsequent transformation of logged-over rainforests into cash crop monocultures (Koh and Gazhoul, 2008; Wilcove and Koh, 2010) [40, 80], such as acacia, rubber and oil palm (Drescher *et al.*, 2016) [15].

According to IPBES Global Assessment Report 2019, land degradation has reduced the productivity of 23% of the global land surface, up to US\$577 billion in annual global crops are at risk from pollinator loss and 100-300 million people are at increased risk of floods and hurricanes because of loss of coastal habitats and protection. The pace of agricultural expansion into intact ecosystems has varied from country to country. Losses of intact ecosystems have occurred primarily in the tropics, home to the highest levels of biodiversity on the planet. 100 million hectares of tropical forest were lost from 1980 to 2000: about 42 million hectares for cattle ranching in Latin America and 7.5 million hectares in South-East Asia for plantation crops. Thus the health of ecosystems on which human and all other species depend is deteriorating more rapidly than ever and eroding the very foundations of our economies, livelihoods, food security, health and quality of life worldwide (IPBES Report, 2019) [34].

#### **Climate mitigation and adaptation**

The world's forests absorb 2.4 billion tons of carbon dioxide (CO<sub>2</sub>) per year, one-third of the annual CO<sub>2</sub> released from burning fossil fuels. Forest destruction emits further carbon into the atmosphere, with 4.3–5.5 GtCO<sub>2</sub>eq/yr generated annually, largely from deforestation and forest degradation. Protecting and restoring this vast carbon sink is essential for mitigating climate change. Forests also play a crucial role in climate change

adaptation efforts. They act as a food safety net during climate shocks, reduce risks from disasters like coastal flooding, and help regulate water flows and microclimates. Improving the health of these forest ecosystems and introducing sustainable management practices increase the resilience of human and natural systems to the impacts of climate change (IUCN, 2017) [36].

#### **Protection of Coastal Zones**

According to the Millennium Assessment Report 2005, Coastal ecosystems—coastal lands, areas where fresh water and salt water mix, and near-shore marine areas are among the most productive yet highly threatened systems in the world. Estuaries are partially enclosed bodies of water, where fresh water from rivers and streams mixes with salt water from the ocean. Estuaries, such as coastal bays, form the transition between the land and the sea; creating a unique, diverse and the most productive ecosystem. Regardless of location or latitude, estuaries, marshes, and lagoons play a key role in maintaining hydrological balance, filtering water of pollutants, and providing habitat for birds, fish, mollusks, crustaceans, and other kinds of ecologically and commercially important organisms. The 1,200 largest estuaries, including lagoons and fiords, account for approximately 80% of the world's freshwater discharge (Alder, 2003; NOAA, 2017) [3].

According to IPCC AR 5 (2014) increasing GHGs in the atmosphere produce changes in the climate system on a range of time scales that impact the coastal physical environment. On shorter time scales, physical coastal impacts such as inundation, erosion, and coastal flooding arise from severe storm-induced surges, wave overtopping, and rainfall runoff. On longer time scales, wind and wave climate change can cause changes in sediment transport at the coast and associated changes in erosion or accretion. Natural modes of climate variability, which can affect severe storm behavior and wind and wave climate, may also undergo anthropogenic changes in the future. Ocean and atmospheric temperature change can affect species distribution with impacts on coastal biodiversity. Carbon dioxide (CO<sub>2</sub>) uptake in the ocean increases ocean acidity and reduces the saturation state of carbonate minerals, essential for shell and skeletal formation in many coastal species. Changes in freshwater input can alter coastal ocean salinity concentrations (Melendez and Salisbury, 2017) [43].

Nearly a quarter of mankind lives in low-lying coastal areas, and urbanization is drawing still more people into them. Commercial activities mostly related to port, shipping, industry and agriculture etc. have delineated to commercial hubs. These hubs are catered by a huge forward and backward linkage activities and establishments like banks and insurance companies, clearing and forwarding agents, warehouses and hotels (NBC, 2009) [48]. Most of the world's biggest cities have grown up around natural harbors. While people have been living in coastal areas for thousands of years, the huge cities and megacities that have grown over the past 100 years have quickly destroyed the natural marine and coastal habitats. Migration for shelter to the cities during the recent extreme climate events, and the sufferings of city-lives exacerbated. The rising sea level endangers several smaller island nations, such as Tuvalu, Maldives, etc., which are barely two meter above the sea level (Brown, 2001) [7]. Millions of people in lowlying regions of many countries including Bangladesh, China (Strohecker, 2008) [73] and Vietnam (Tanh and Furukawa, 2007) [75] face the danger of being displaced. The construction of general infrastructure such as roads, houses, shops, factories, airports, and ports

completely replaces natural habitats. Estuaries, deltas, and their rivers are often dredged and deepened to cope with increased shipping. In addition to this, impacts such as increased erosion due to coastal development, increased pollution, and boat traffic etc., which lead to further habitat loss and put increased pressure on marine species (Rahman and Rahman, 2015) [61].

### Restoration of Hydrological Cycle through Water table and Watershed Management of the Mountain and Hill Forests

Mountains and the hills are the important sources of water supply to the valleys, foothills and down the plains through gullies, streams and rivers. Forest and vegetations are the integral parts maintaining hydrological cycle upholding water-table through transpiration pool, evaporation, precipitation, percolation and seepage. Springs and watersheds provide water to forest biodiversity with huge animals, amphibians, birds and reptiles etc. (Winter *et al.*, 1998) [81]. Destruction of the natural forests, hydrological cycle is being disturbed resulting drying up of perennial springs and streams; disrupting the water table and thus affecting forest ecosystem. Illicit logging, replacement with economically profitable plantation crops mainly with monocrops *viz.* timber, paper and pulp wood, rubber, oil palms, tea, cocoa, banana, soybeans and tobacco etc. have affected the hydrological cycle and damaged huge biodiversity thus changed the ecosystems and made more vulnerable to wildfires and droughts. Massive plantation of deciduous timber trees like Teak and Gmelina; resinous and oily Pines and Eucalyptus and xerophytic Acacias in the tropical and subtropical humid and rainforests is the main reason for disrupting the hydrological cycles (IUCN/WWF 2006, Basak *et al.*, 2015) [85]. Nearly all

surface-water features *viz.* streams, lakes, reservoirs, wetlands, and estuaries interact with ground water. As a result, withdrawal of water from streams can deplete ground water or conversely, pumping of ground water can deplete water in streams, lakes, or wetlands. Pollution of surface water can cause degradation of ground-water quality and conversely pollution of ground water can degrade surface water. Thus, effective land and water management requires a clear understanding of the linkages between ground water and surface water as it applies to any given hydrologic setting (Winter *et al.*, 1998) [81].

### Need for a Healthy Ecosystem Management

Feeding the world at a time of climate change, environmental degradation, increasing human population and demand for finite resources requires sustainable ecosystem management and equitable governance. Ecosystem degradation undermines food production and the availability of clean water, hence threatening human health, livelihoods and ultimately societal stability. Degradation also increases the vulnerability of populations to the consequences of natural disasters and climate change impacts. Here ecosystem management can be defined as an integrated process to conserve and improve ecosystem health that sustains ecosystem services for human well-being (TEEB 2010; Norton, 1991 and Costanza, 1992) [77, 50, 12]. Healthy ecosystems and their services provide opportunities for sustainable economic prosperity while providing defense against the negative effects of climate change (TEEB 2010 and Meckey, 2009) [77] through human adaptation and behavioral change, as opposed to a continuation of degradation (Figure-1) Munang *et al.*, 2011 [45].

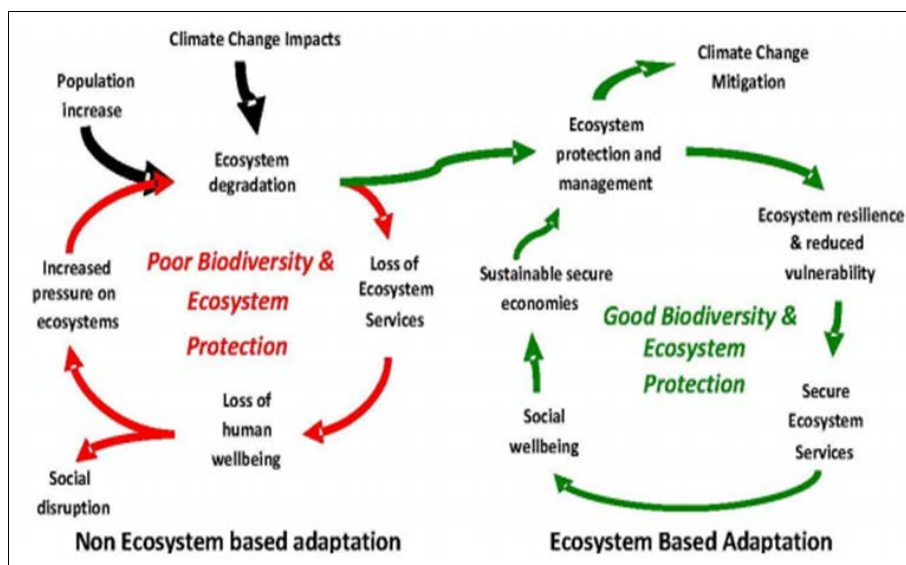


Fig 1: Beating the vicious cycle of poverty, ecosystem degradation and climate change  
Source: Munang *et al.*, 2011 [45]

### Restoring tropical forests

The tropics lost 12 million hectares of tree cover in 2018, the fourth-highest annual loss since records began in 2001, according to forest monitoring service Global Forest Watch (WRI, 2019). Restoring tropical forests is fundamental to the planet's health, now and for generations to come. Protecting existing forests and restoring damaged ones prevents flooding, stores carbon, limits climate change and protects biodiversity. Some countries, including China, India, Malawi, Cameroon and Ivory Coast, have already launched large-scale tree planting efforts with some success. Plantation of tropical rainforest areas

would produce the highest benefits for safeguarding wildlife, curbing and adapting to climate change, and boosting water security. The top 15 nations with the largest reforestation hotspots included Brazil, Indonesia, India, Madagascar, Colombia, the Philippines, Vietnam, Myanmar and Thailand. The six countries with the greatest potential for successful rainforest restoration were all African: Rwanda, Uganda, Burundi, Togo, South Sudan and Madagascar. More than 70% of the hotspots were found in countries that have already made reforestation commitments under the Bonn Challenge, agreed by nations in Germany in 2011 and 350 million hectares of

degraded land worldwide to be restored by 2030 (Taylor, 2019)<sup>[76]</sup>. It should be noted that for successful establishment secondary forests trees should be chosen according to their habit and habitats i.e. right plant at right place (Kallio, 2013; Basak *et al.*, 2015)<sup>[39]</sup>.

### Floodplain Management

Traditional floodplain management by digging ponds and raising land for homes vegetation with forest groves a unique adaptation practice for defending floods, water uses, fish culture, and to protect houses from cyclones and tornados in the Ganges and Brahmaputra basin in South Asian region; cross-sectional view shown in Fig. 2 (Dewan, 2015; Rahman and Rahman, 2015a; Rahman *et al.*, 2018)<sup>[13, 62-63]</sup>.



**Fig 2:** Cross-sectional view of traditional flood-plain management  
Source: Rahman and Rahman 2015a<sup>[61]</sup>

### Agriculture in Adverse Situation

Growing crops in the adverse environment manipulating the climatic and environmental factors are becoming effective and gaining importance in adverse climatic situation towards food security. The common practices are greenhouse agriculture, hydroponics and aquaponics also known as the integration of hydroponics with aquaculture (Diver, 2006)<sup>[14]</sup>, and floating agriculture. Floating gardens are age-old practice of crop cultivation in the Southern floodplains of Bangladesh. Floating garden agricultural practices for growing vegetables and spices prevail in the wetlands of the south central coastal districts of Bangladesh since immemorial times. With the use of available water hyacinth and other aquatic weeds, local communities have developed a technique to construct reasonably-sized floating platforms or raft on which vegetables and other crops can be cultivated (APEIS and RIPSO, 2004 and FAO)<sup>[5]</sup>. It is also practiced in India (Chatterjee, 2016), Myanmar (NASA, 2015)<sup>[9, 47]</sup>, Mexico, China and Thailand (Pantarella *et al.*, 2011)<sup>[53]</sup>.

### Agroforestry

Climate variability is well buffered by agroforestry because of permanent tree cover and varied ecological niches. Resilience, or recovering after a disturbance is well performed by agroforestry because of diversified temporal and spatial management options; permanent tree cover protects and improves the soil, while increasing soil carbon stocks. Agroforestry provides varied ecological niches allow for the presence of different crops, e.g. shade-tolerant and light-demanding and diversification of commodities allows for adjustment to market needs. It offers a win-win opportunity by acting as sinks for atmospheric carbon while helping to attain food security, increase farm income, improve soil health and discourage deforestation (Rao *et al.*, 2007; FAO, 2013)<sup>[64, 25]</sup>.

### Urban Greenery

With the increasing impact of climate change, the increasing migration of populations to urban areas and a deterioration of the environmental and social quality in cities, the need to

implement solutions to limit the impact of these factors on the quality of life induced the European Commission to launch the priority topic of the Nature-Based-Solutions (NBS). It sequesters local carbon, decreases the pollution, lowers the temperature, increases biodiversity, and provide pleasant environment for recreation (European Commission, 2015 and Calfapietra and Cherubini, 2019)<sup>[20, 8]</sup>. Paris has just announced that it will be planting a series of urban forests as a way to combat climate change. The mini forests will center around the Gare de Lyon, the Palais Garnier, and pathway along the banks of the Seine river. This planting scheme is part of a wider goal to make 50 per cent of the city's surfaces vegetated and permeable. It is also a part of Paris' aim to be a carbon neutral city by 2050 (Stinson, 2019)<sup>[71]</sup>.

### Urban Agriculture, Urban Water and Waste Management

Urban agriculture, urban farming, or urban gardening is the practice of cultivating, processing and distributing food in or around urban areas. Urban agriculture can also involve animal husbandry, aquaculture, agroforestry, urban beekeeping, and horticulture (Wikipedia). Urban agriculture provides fresh food, generates employment, recycles urban wastes, creates greenbelts, and strengthens cities' resilience to climate change. Urban and peri-urban agriculture can make an important contribution to household food security, especially in times of crisis or food shortages. Produce is either consumed by the producers, or sold in urban markets, such as the increasingly popular weekend farmers' markets found in many cities. Because locally produced food requires less transportation and refrigeration, it can supply nearby markets with fresher and more nutritious products at competitive prices (FAO, 2019)<sup>[27]</sup>. Practical Action is working through water supply, sanitation and hygiene (WASH) programmes to promote the community-led total sanitation approach with partners and local governments, demonstrating best practice and developing innovative technologies for clean water and waste management with national and city governments to ensure that poor people are included in sanitation planning (Practical Action, 2019)<sup>[60]</sup>.

### Climate Smart Agriculture (CSA)

It is an integrated approach to managing landscapes, cropland, livestock, forests and fisheries that address the interlinked challenges of food security and climate change (World Bank, 2018). With rainfall declines and an increasing global temperature threatening the livelihoods of many smallholder farmers, 'climate-smart agriculture', a concept developed by the Food and Agriculture Organization of the United Nations (FAO) in 2010, has been adopted to respond to the challenges of climate change and enhance the capacity of agriculture to support food security in a sustainable way. CSA has since helped in the creation of crops and adoption farming practices that are resistant to climate change while increasing agricultural productivity and reducing greenhouse gas emissions in the process. CSA aims to simultaneously achieve three outcomes:

1. Increased productivity: Produce more food to improve food and nutrition security and boost the incomes of 75% of the world's poor who live in rural areas and mainly rely on agriculture for their livelihoods.
2. Enhanced resilience: Reduce vulnerability to drought, pests, disease and other shocks; and improve capacity to adapt and grow in the face of longer-term stresses like shortened seasons and erratic weather patterns.
3. Reduced emissions: Pursue lower emissions for each calorie or kilo of food produced, avoid deforestation from

agriculture and identify ways to suck carbon out of the atmosphere.

### Mitigating and Adapting to Climate Change in Bangladesh

Bangladesh is recognized internationally for its cutting-edge achievements in addressing climate change. Bangladesh has invested more than \$10 billion in climate change actions – enhancing the capacity of communities to increase their resilience, increasing the capacity of government agencies to respond to emergencies, strengthening river embankments, building emergency cyclone shelters and resilient homes, adapting rural households' farming systems, reducing saline water intrusion, especially in areas dependent upon agriculture, and implementing early warning and emergency management systems. The World Bank, International Finance Corporation and the 2030 Water Resources Group have also collaborated on an investment strategy for the Bangladesh Delta Plan (BDP) 2100, a long-term investment program to spur adaptive management of the Bangladesh Delta (World Bank, 2016). BDP 2100 is indeed the combination of long-term strategies and subsequent interventions for ensuring long term water and food security, economic growth and environmental sustainability while effectively reducing vulnerability to natural disasters and building resilience to climate change and other delta challenges through robust, adaptive and integrated strategies, and equitable water governance (Alam, 2019) <sup>[2]</sup>. Bangladesh has also developed salinity tolerant rice varieties *viz.* BRRI dhan55, BRRI dhan61 and BINA dhan8, BRRI dhan47, 48 and BRRI dhan28 (Islam *et al.*, 2016) <sup>[35]</sup>.

### Conclusion

Ecosystems are integral parts of the living system provide food and other livelihoods through interactions of living and nonliving surroundings. They have profound influences on climate vis- a-vis climate is also a limiting factor that influences the ecosystems. As human activity dictating over the ecosystems and altering in many forms *viz.* created agricultural field ecosystem, home-centered floodplain ecosystem, manmade pond ecosystem, urban and peri-urban ecosystem etc. many changes have occurred resulting climate change and biodiversity loss. Quick changes in ecosystems due to increased population in the last two centuries especially for agriculture, industrial expansion and infrastructure development have caused an immense effect on the ecosystems. Therefore, rational utilization of resources and logical management of ecosystem are utmost essential to adjust with the climate impacts. Fundamentally, ecosystems are the foundation of life support and hence it requires appropriate protection and management at a level commensurate with their true value in supporting the global economy. It is vital, therefore, that the issue of ecosystem management has to be integrated with other measures to address food security and climate change. It is recommended that an ecosystem approach becomes centrally embedded within local, national, regional and international level planning and policy making to ensure ecosystem health to give a food secured world.

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