Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online): 0493-2137
E-Publication: Online Open Access
Vol:54 Issue:07:2021
DOI 10.17605/OSF.IO/95YEU

IMPACT OF RURAL ACTIVITIES ON BIODIVERSITY AND ECOSYSTEM SERVICES

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Abstract

For a wide variety of natural resources and ecological services necessary for their well-being, rural poor typically rely on diversity and are thus likely to be tormented by their deprivation. Conservationists, development practitioners and policy makers generally have different views about how and whether to link conservation of diversity with poverty reduction in this context. Rural inhabitants notably valued provisioning structural/ecosystem services like fuel, water, and crops, however ignoring the many important regulatory and supporting services. The flow of environmental services is not only vital for rural ecosystems and well-being of poor rural communities. Anthropogenic activities are mainly responsible for habitat fragmentation and destruction of bio-cultural resources and responsible for minimizing the delivery of ecosystem services. The intensification of agriculture in rural areas is one of significant causes for biodiversity losses besides many other human perturbations decreasing the both quantity and quality of ecosystem services. The ecosystem services, biodiversity and socio-economic development have linked in complex ways with several feed backs operating within and between systems. The growing demands by burgeoning population further deteriorating balance and links between the components. Therefore, the quantification of biodiversity and ecosystems are critical in rapidly changing rural ecosystems. The policy frame work for management of biological diversity and ecosystems services needs to revitalize aligned with goals and targets of SDG aimed at sustainable development of communities. The synergies and trade-offs needs to be carefully balanced for managing biodiversity and development and nexus in food-energy water related

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ecosystem services. The chapter reviews the nature based socio-ecologically engineered solutions for regenerating eroding diversity and bringing resilience in rural ecosystem services.

Key words: Biodiversity, Ecosystem services, Human activities, Rural Sustainable development

1. Introduction

Rural landscapes are heterogeneous land masses encompass diverse ecosystems support wide variety of living and nonliving entities interdependent and interlinked to each other with specific roles and functions.The evolutionary process over millions of years has created huge diversity among animals, plants and micro-organisms. The variety and variability among organisms reflect the nature and wealth of biodiversity. Biological diversity is corner stone, provides several benefits and provides many ecosystem services to rural communities since immemorial times. The survival and existence of human beings on planet earth are dependent on biological richness and diversity of a particular region. Almost 45% of population lives in rural areas in the world, while 75% in developed countries. Most of the rural areas are in crisis, communities facing the brunt of poverty, malnutrition and poor quality of life. Rural people comprise 70% of the world extremely poor. The rural wellbeing and prosperity intrinsically linked to natural biodiversity, including diverse ecosystems that supply a wide range of goods and services to meet the needs of both local and global communities. Rural people are mostly agrarian communities deeply interwoven with complex nature and functions of natural and manmade ecosystems including agriculture, forestry, grasslands, deserts, fresh water and marine ecosystems (McLaughlin and Mine au 2005). They exploit rich diversity as direct source of rural livelihoods and household income. The diversity also renders important indirect benefits through assisting pollination, biological control of pests, paedogenesis, recycling of water and regulating climate. However, in recent years the rural places are becoming unattractive habitat due to fast dwindling sources and deteriorating quality of life. Biodiversity is very vital and key for sustainable rural livelihoods, particularly relevant in the context of global change processes. Biodiversity is the basis of agriculture and our food systems, which has strong bearing on survival of resource-poor communities suffering from poverty and unemployment in rural areas. Small-scale farmers also greatly depend on ‘wild’ (non-farmed) plant and animal resources for food, fuel, timber, medicine, fibre etc. Such resources cater the need of basic domestic requirements and supplement house hold income. The livelihoods of small holding farmers in rural areas are built on genetic diversity embedded in cultivated or natural ecosystems including forests and wetlands (Sahoo et al. 2020). The broad genetic diversity builds resilience in crops and livestock to survive and adapt to shocks of biotic and abiotic stresses, such as droughts, water logging, outbreaks of pests and diseases. It further allows developing desirable traits to withstand drought or improved quality by exploiting the wild varieties and crossing relative families abundantly found in surrounding wild land ecosystems.

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2. Biodiversity & Rural Ecosystem Services

Aerts and Honnay (2011) states that biodiversity is central for production of range of ecological services and extending multiple benefits to rural societies, which in turn contribute to co-existence and well-being of rural ecosystems. Biodiversity is basic for supporting environment wellbeing, wherein health allocation, water decontamination, flood and dry season control, biogeochemical cycle, and environment guideline administrations are kept up. These amenities are crucial to support economic and bio-cultural development. In spite of the substantial contribution of biodiversity for economic, social and cultural development, it losses are huge and in some areas at very alarming rates especially in rural areas in tropical countries. Biodiversity controls the aptitude of ecosystems to supply the environment facilities, which is exploited to fulfil the material needs of people and is valued by societies for its intangible contributions mostly undermined. Ecosystem services are contribution of the goods and services from ecosystems are indispensable for the benefit and wellbeing of the people that are coproduced by complex interactions between ecosystems and societies (MEA, 2005; TEEB, 2010; Wani and Sahoo 2020). Rural societies are deeply connected to diverse ecosystems both spatially and temporally, as they depend on several provisioning ecosystem services as source of household income and livelihood. Biological system administrations are provided in packs instead of individual, while certain gatherings of administrations are more effectively open than others. The act of a social-environmental framework idea permits the utilization of biological system administrations in much better thorough manner, which is normal in country zones developing fisheries and raising domesticated animals in rice developing belts (Adams et al. 2018). Hence, the possibility of being poor differ in space with the accessible sets of ecosystem services and closeness to some geographical entities discerned with coast or major rivers, or access to roads and cities. The ecosystem services benefitting the rural communities are mainly classified into the following

2.1 Provisioning Services

Provisioning services are the tangible products/raw materials those extracted from ecosystems and can be directly utilized and traded in markets (Wani and Sahoo 2020). However, rural households directly depend on provisioning services for their livelihoods, which is more important than market value. Food is among the most important provisional services of rural ecosystems. Foods can be provisioned through the practice of agriculture, aquaculture, hunting, gathering, and fisheries. Besides, the other important services falling under this category are firewood, timber, fodder, fibres, medicine etc.

2.2 Regulating Services

Regulating services are invisible ecosystem processes to ecosystem functioning that influence the wellbeing and ecological health. Regulating services are drivers that influence climatic change, spread of pests, crop pollination, soil formation and flood control. Besides, these services maintain environmental quality through moderating

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soil, air, water and weather conditions of ecosystems and habitability (Wani and Sahoo 2020).

2.3 Supporting services

Ecosystems could not able to sustain themselves without the support of ecosystem processes like net photosynthesis, recycling of nutrients, paedogenesis, and cycling of water. All the above processes are essential for functioning of basic life forms, ecosystems and people. Without supporting services, it will not be possible to secure provisional, regulating, and cultural services. Therefore, the supporting services become necessary for delivering other services, and also support habitat/ living places for flora and fauna thus maintaining biodiversity and supply services for societies, which includes

i) Biogeochemical cycling
ii) Paedogenesis
iii) Seed dispersal
iv) Primary production
v) Habitat

The significance of biodiversity behind the stockpile of the two products and biological system administrations controlling the environment measures is generally perceived (Díaz et al. 2006; MEA, 2005), and conceptualizing the biodiversity–biological system administrations relationship and the inconvenient effect of biodiversity misfortune on the conveyance of environment administrations is acquiring significance as of late. Inside the framework, keeping up exact ecological undertakings are essential to food and supply a particular eco framework administrations for example essential creation and fertilization for food creation, water penetration limit with regards to water arrangement and natural deterioration for soil ripeness. These particular capacities rely upon explicit piece of biodiversity and frequently, expanding biodiversity will enhance the effectiveness. Several studies proved that biodiversity regulates the flow of ecosystem services to societies by maintaining functional diversity of diverse ecosystems (de Bello et al. 2010; Díaz et al. 2006). Biodiversity regulate the provisions from diverse ecosystems including agriculture, forestry, grasslands, deserts, fresh water and marine ecosystems.Accordingto the reports of Costanza et al (2014) about 125-145 trillion US $ per year to the global economy was contributed by ecosystem services and support billion poor people meeting livelihoods in the world.

About40% of the continental surface of the earth is covered by agriculture, which is the mainstay and primary occupation of rural population in many developing countries. Agro-ecosystems in rural settings that both provide and utilize ecosystem services, which need practical attention to maintain valuable biodiversity, and sustainable yields along intrinsic socio-ecological values (Lescourret et al. 2015).It provides direct food provisioning service that is much more important essential commodity of rural households than its market value. Both wild and managed ecosystems provide food and nutrition prerequisite for survival and health of rural

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people. Global aggregate food production currently is adequate to meet the requirements of our appetite but there is huge regional disproportion in food production systems and rural livelihoods largely affected by socio-economic and ecological conditions. Millions of people in rural areas are experiencing hunger and poverty, mostly represented by African and Asian countries. Food insecurity, malnutrition and under nutrition are recognized as chronic problems in rural areas, as the people in low-income countries - do not get recommended levels of protein and calories for energy (Persha etal. 2011). Several communities are prone to deficiencies of micronutrients (vitamins, zinc and iodine). In rural areas, the health of people is much dependent on native ecosystems that supplement basic food and nutrition. The nutritional disparity is growing among stakeholders due to increasing socio-ecological changes. Native ecosystems are critical to ensure traditional dietary needs because the poor communities neither have the capacity of buying nor access to variety of foods. Wild plants and animals are significantly consumed and partially meeting hunger and malnutrition in rural areas (Rissman and Gillon 2017).

Farmers, especially in developing countries, still use local crop varieties or landraces in rural areas that not only help in maintaining crop diversity but also cope with extreme events. Genetic diversity builds resilience in crops to withstand against abiotic and biotic stresses that reduce fluctuations in yields and increase the adaptability. Agricultural landscapes, including low to high diversity agro ecosystems have a wide range of adaptation and resilience, while producing variety of food commodities (Power 2010). The synergies and trade-offs of food production from agricultural sector need to be carefully analysed while ensuring the balance agro-biodiversity and provisioning ecosystem services. Agriculture systems should not be perceived as supply food provision alone but also deliver an entire package of multiple ecosystem services including supporting, regulatory and cultural services. Agriculture systems play key role in providing services on soil fertility, pest control and pollination, water quality, spiritual and cultural dimensions which are deeply connected with societies and ecosystems. The well managed agro-ecosystem supports on farm diversity and also maintains habitability for many life forms. The regulating effects of conservative agriculture could not be undermined especially the processes related to soil formation, C sequestration, nutrient recycling, soil conservation, slope stabilization and hydrological cycling (Gaucherel and Pommereau 2019). The aesthetic, recreation and cultural benefits have long been recognized from agriculture. However, the expansion and unplanned increase of agricultural systems in vast extent of natural forests and grass lands for increasing the provisioning services of food have several negative impacts on biodiversity in rural landscape. The widespread encroachment is not only the measure cause of biodiversity loss but also responsible deplete the number of ecosystem services, which may create imbalance in biodiversity and ecosystem services, which can jeopardize the sustainable development of societies and ecosystems. Therefore, firm policies and decisions balancing both synergies and trade-offs on agriculture sector needs to be carefully addressed to maintain on-farm biodiversity and ecosystems in rural areas (Rissman and Gillon 2017).

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Forest ecosystems and biodiversity intrinsically linked to integrity, health and vitality of surrounding ecosystems, while the losses in forest biodiversity not only result in declined functions but also indirect effects on other ecosystems. Therefore, sustainable forest management is advocated to ensure biodiversity conservation and regulate the supply of ecosystem services. High levels of biodiversity capable of delivering multiple services in a balanced way are one of the main objectives of conservation and sustainable utilization of forest resources. Rural societies derive wide array of products mostly as provisioning services from forests that include timber, fuelwood, fiber, pharmaceuticals, and industrial products (Alamgir et al. 2016; Quintas-Soriano et al. 2016; Rout et al. 2020). Apart from these essentials, forest and grass lands support rearing of livestock under silvopastoral systems (Peri et al. 2016;) for supplying products like milk and its products, bush meat, wool, leather etc.

The forests provide many provisioning ecosystem services to rural societies as more than 1.6 billion people exploit biological diversity as source of livelihood. Of which 300 to 350 million are aborigines live in vicinity of dense forests and rely on forests for material and non-material goods. Many studies reported that tangible and intangible goods contributed between ca. 47% and 89% of the total source of livelihood for rural and forest-dwelling communities (Alamgir et al. 2016). According to a study, it is estimated that forest contributed between 20 and 28 percent of their rural household incomes in Latin America, Africa, and Asia. Forests provided more income than labour, livestock, self-owned businesses, or any other category apart from agriculture, as 50% of this is non-cash that constitute food, fodder, energy, house-building materials, and medicine, which is “hidden harvest,” especially important for the poor with limited access to markets.

Apart from provisioning services, forests and grasslands in rural areas offer many important hidden regulating services mainly climate regulation, decomposition, recharge and purification of water, flood control, pollination etc. It is well recognized that forests play significant role in C sequestration and mitigating the negative impact of climate change (Prusty et al. 2020). Forests and grasslands store a large amount of atmospheric C in the vegetation and soil, thus regulate the process of global change. Primary and regenerating forests remove the C from the atmosphere at much faster rates (Beer et al. 2010; Pan et al. 2011; Lal and Lorenz 2012), and resilient against flood and droughts. The monoculture attracts a large number of pests, while diverse forest ecosystems help in reducing the pest and disease population in crops growing in rural areas. The population of natural enemies and large number predators are found in forests help in natural control of pests and further the presence of biochemical constituents in plants reduce incidence of pests. Variety of insects and birds such as wasps, owls, parrots, batsetcliving in forest help in biological control (González et al. 2015; Karp et al. 2015; Quintas-Soriano et al. 2016).

Forests play a vital role in soil formation, soil development and control of soil erosion on undulating topographies. Forest soils regulate the flow of nutrients, water and carbon between ecosystems(Kreye et al. 2014; Sun and Vose 2016).Undisturbed forests usually maintain rich biological diversity than disturbed forests, which supplies several goods (genetic and biochemical resources) while interacting with its

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own and other ecological systems (Daily and Ehrlich 1995). The diverse plant species support habitat for wild animals used as dispersal agents where in propagules are disseminated to distances with ease (Bregman et al. 2015; Peres et al. 2016). The forests extend recreation and aesthetic benefits together with intellectual and socio-cultural services in the form of landscape photography, avian study, sports, games, ecotourism, trekking and survey are some examples. The forests are one of the great sources of rejoice, tranquility, peace and mental and psychological benefits (Daily and Matson 2008).

Aquatic ecosystems in rural areas including fresh water and marine water bodies are unique and productive ecosystems that support diverse habitats and biodiversity and well recognized as life line of rural societies by extending multiple ecosystem goods and services. The services related to water are received renewed attention in recent times as it is elixir of life and therefore valued in almost all wakes of life including agriculture, industrial and domestic uses. The ponds, lakes, dams, reservoirs, rivers, flood plains, coastal water bodies like estuaries, salt marshes, mangroves, deep sea and ocean bodies provides provisioning, regulating, supporting and cultural services to communities (Rissman and Gillon 2017). Food is the most important provision mostly derived from animal and plant components living in water bodies. Variety of fishes, prawns, shrimps, molluscs, crustacean shells, lobsters, mussels, oystersetcare regularly harvested, besides hydrophytes supply leafy vegetables, roots, stems, flowers etc. sea weeds and microalgae also serve as source of food in rural areas. The aquatic foods are significant source of protein especially in those regions where problems of food insecurity and protein deficiencies are persistent (Golden et al. 2016), the supply of seafood tackle vulnerable communities in coastal regions (Belton et al. 2018).

The aquatic systems play an important role in nutrient cycling, soil conservation and purification of water by filtration. They play important role in C cycle and waterbodies stores a large amount of CO_2 and regulate the climate change process (Prusty et al. 2020). Habitats created by plants and animals such as sea grass meadows, burrows by crabs, bed of horse mussels play crucial role in survive under extreme conditions and reducing erosion by tidal waves and forming solid sediment line along sea shores (Grabowski et al. 2012).The supporting services provided by aquatic bodies include living spaces for diversity of plants and animals which could thrive only in aquatic systems. Cultural benefits are collectively associated spiritual and physical benefits drawn from aquatic resources. Benkendorff (2009) considered that cultural labelling of fish as unique symbol reflect good health and social curing in ethno medical practices among traditional communities. The way the indigenous communities to maintain and preserve biodiversity is deeply rooted in their custom and culture. For e.g. the tribal communities employed temperate seaweeds as remedy, attached to the spiritual and physical connections ultimately became traditional custodians of Mari culture development (Thurstan et al. 2018).

3. Drivers of biodiversity losses and decline of Ecosystem Services

Millennium Ecosystem Assessment (2005) highlighted that "*biodiversity loss and deteriorating ecosystem services contribute - directly or indirectly - to worsening*

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health, higher food insecurity, increasing vulnerability, lower material wealth, worsening social relations and less freedom for choice and action". Large scale destruction and degradation of natural ecosystems are major cause of loss of diversity from natural ecosystems. It is very tragic that many fragile rural landscapes across the world are suffering from vagaries of unscientific exploitation and mismanagement and posing serious threat on existence and survival of cultures and ecosystems (Xiao et al. 2019). The rate of extinction of different levels of biodiversity has alarmingly increased over the last few decades through destruction of habitats and ruining natural environment.

Anthropogenic activities have already degraded nearly a billion ha of land across the world by expansion commercial agriculture and industrial activities. Thus, habitat loss heavily eroded the biodiversity and declines the important ecosystem services, threatening livelihood security and causing socioeconomic instability in rural areas. The cost-effective, socially-acceptable, and nature based solutions needs to be practiced to reinvigorate and restore functioning of ecosystem (Rissman and Gillon 2017). As the ecosystems in rural landscapes are under tremendous pressure and altered by destructive human activities, resulting in degradation of productive to unproductive systems. Although the underlying drivers are still being debated, there is compelling evidence that biodiversity losses is already modifying the rural ecosystems, leading to decrease in regulatory and supporting ecosystem services in rural areas, this has become true when people are migrating to urban areas in search of employment and livelihoods (Xiao et al. 2019).

The unprecedented losses of biodiversity not only affected the intrinsic ability of the ecosystems but also diminishing basic ecosystem services that regulating climate change, filtration of water and air, supply of medicines and other provisions. There are several causes of biodiversity losses and mainly due to 1) Land use changes and habitat destruction (2) Poaching and illegal hunting (3) Unscientific exploitation (4) Landscape fragmentation (5) Collection for Research (6) Introduction of exotic/alien Species (7) Environmental pollution (8) Use of agro chemicals (9) Natural disasters and (10) Miscellaneous items.

Habitat destruction through expansion of agriculture, rural settlement, mining, construction multipurpose dams, roads, railway tracks, natural disasters- landslides, floods, storms, uncontrolled fire, earth quakes etc. is quite evident. The increased levels of water and air pollution, global change phenomenon not only affected diversity of biological resources but also declined ecosystems functions to regulate the climate. The introduction of alien/exotic species, indiscriminate harvests of fisheries, timber, fire wood, fibre and certain birds and mammals and inappropriate management are largely responsible degradation of native biodiversity.

The expansion of agricultural lands by transforming the forest and grassland ecosystem for meeting the provisions of food and nutrition in last few decades have deteriorated the biodiversity and intrinsic abilities of functioning of self-sustaining ecosystems. The practices of agricultural intensification and commercial agriculture in rural areas eroded the biodiversity and affected the ecosystem services, which have negative effects on ecosystem functions and human well-being. About 40% of

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earth's land surface is transformed into one or other forms of agriculture (Clark and Tilman 2017), as it is alone major cause and key drivers of biodiversity loss and ecosystem services (IPBES 2016). The faulty agricultural released 133bn tonnes of soil C to the atmosphere (Mori et al. 2017) and similarly calcium 70% from withdrawal of freshwater water for variety of uses. The relentless increase in ill managed agricultural activities acting as precursor for modifying human footprint (Poorter et al. 2015), and warrants to conserve the last remnant ecological landscapes keeping in view of the current and future needs of biodiversity and ecosystem services in the context of climate change (Dinerstein et al. 2013).

Human perturbations causing landscape fragmentation is one of the major concerns for loss of habitats and biodiversity in rural areas. It leads to breaking of large continuous ecosystems in to isolated disconnected small patches, which increases with intensity of biotic interferences and disturbances. The separation and kind of exposure to human inferences could alter the structure and functioning of leaf over fragments. Ecologists argue that landscape fragmentation is alarmingly increasing and ecosystems are facing overburden of increasing demands. Davis et al. (2017) in a study from five continents reported that fragmentation of habitats resulted in decline of 13 to 75% of biodiversity and impaired the key functions of ecosystem by decreasing biomass and modifying nutrient cycles. The degree of biotic interference affects the size and density of the patches. If higher the disturbance, the fragmentation will be more result in increased density and decrease the size of patches, which will decrease the diversity (Rissman and Gillon 2017). The smaller patches are highly vulnerable, experience marked variation in microclimate that existed in the habitats before fragmentation. The soil and air temperature will be usually higher at the edges of fragments; light can deeply penetrate into the edge exert significant influence on regeneration and development of existing species. The edges are prone to be colonized by hardy invasive alien species, which badly affect the structure and function of indigenous species. The remarkable losses in biodiversity and ecosystem services due to fragmentation are now widely recognised across rural ecosystems (Irvine et al. 2019). The fragmentation isolates populations of a species into smaller sizes. Decrease in habitat fragmentation leads to “win” situation which will not only decrease rate of species extinctions but contribute for holistic development of ecosystems and societies and ensure multiple ecosystem services in rural areas.

4. Linking Biodiversity & Ecosystem Services

Ecosystems usually provide set or bundles of ecosystem services to societies with multiple links and feed backs with double edged sword. Biodiversity regulates the flow of ecosystem services in which much complex way and specific to the type of ecosystem. In a given ecological system, the explicit functions are mandatory to deliver inexplicit service. For example, primary production and pollination for food, water purification for water, and organic matter decomposition for soil quality. The particular function relies on particular component of biodiversity, while increase in biodiversity will optimise these functions. The extinction rates of species dramatically increased up to tune of 1,000 to 10,000 times the normal rates in the last few centuries (Chivian & Bernstein 2004; Isbell 2015; Rout et al. 2020).

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The current trends in loss of biological diversity compared to past be posing serious threats to biodiversity, continuous supply of ecosystem services and our wellbeing, which are intimately linked. This loss of biodiversity destabilizes the ecosystem functions and services, which in turn affect our wellbeing (Millennium Ecosystem Assessment, 2005). Understanding the complex links between biodiversity and ecosystem services has been started in the last few decades, and the people are realizing the real value of this link for socio-ecological development, which was largely undermined.

In rural areas, biodiversity and nature-based solutions are poorly understood in the social–ecological sense. Human responses to a major threat to biodiversity and its direct effects on ecosystem services can elicit a number of feedback loops. For example, building a road network can fragment the landscape and reduce species richness, which will have direct effects on hydrology and landscape nutrient cycles, affecting water supply, even though water quality is unaffected by species richness (Gamfeldt et al. 2009; Dash et al. 2020; Tripathy et al. 2020). Moreover, human responses to the development of road network leads to disturbances ecosystem configuration, hydrology, nutrient cycling, and freshwater resources (Costa-Pierce and Bridger 2002).

5. Mainstreaming Biodiversity conservation & Ecosystem Services in Rural Landscapes

Revitalization and transformation are desperately needed to address growing demands on ecosystem services and biodiversity in rural landscapes. There is serious concern on halt the process of ecosystem degradation due to ill planned human activities, which can be useful for gaining only short term benefits exposing the communities' to face long-term cascading effects that could severely impacts the lifestyles and economy of rural households. Therefore, the management of biodiversity and ecosystem services are crucial to regulate the capacity of the ecosystems to ensure the continuous supply of ecosystem services, to meet multiple direct and indirect goods and services (Gamfeldt et al. 2013). Monitoring of biodiversity alone is not adequate but it is also necessary to consider the ecosystem services while formulating policies secure human needs and regenerate ecosystems to change into more sustainable and inclusiveness in rural areas. They create new economic opportunities, employment, socio-cultural aspects to attract the people to continue their lifestyles and avert migrations. Both qualitative and quantitative information on wealth of bio resources and ecosystems services are needed for planning and implementing site specific decisions for sustainable development. The documentation of biological resources and supply of ecosystem services, indigenous knowledge and benefit sharing on equitable basis are pre requisite for optimum planning and sustainable management of rural biodiversity (Bullock et al. 2018).

Despite the several efforts taken to conserve biodiversity to achieve "2020 target" of to offset biodiversity losses could not be met. Assessments of MEA and The Economics of Ecosystems and Biodiversity (TEEB) draw the attention on consequences on loss of diversity on welfare of societies by preaching the value of biological diversity and ecosystems in sustaining rural livelihoods, economies and

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social development. The ecosystem services (ES) and biodiversity if not included in economic decision-making might degrade natural capital. Most of ecosystem services are perceived as public goods and free to utilize without bothering about the sustenance. Many of the services have unrecognized in planning and development process leading degradation of many ecosystem process (Wani and Sahoo 2020). The identification of multiple ecosystem services benefiting the societies needs to understand in the context of biodiversity and socio-cultural aspects which are undermined till recent years.

In order to gain a holistic understanding of ecosystem services, four distinct components must be measured and monitored: supply, distribution, contribution to well-being, and benefit (Tallis et al. 2012). Supply refers to the ability of a socio-ecological system to produce a specific service, which is typically expressed as a flow (i.e., amount/time). The term "delivery" refers to the quantity of a service that is taken (for example, the quantity of wood harvested), used (for example, an area free of flood damage), and then delivered to communities (e.g., spatial location of those benefiting from flood regulation), Contribution to prosperity alludes to the adjustment in individuals' prosperity, which comes about because of eating, utilizing, or approaching the help. Changes in wellbeing status, better living or satisfaction halfway rely upon the conveyance of environment administrations. Worth records for the general significance of the assistance credited to a general public. The estimation of biological system administrations is regularly accounted in money related terms yet non-financial valuation is similarly significant for certain administrations (MEA 2005).

Characterization and mapping of biodiversity and ecosystem services at varying spatial and temporal scales are essential for accounting the natural capital. The maps generated at one spatial scale can be refined using data produced from other multiple scales. It creates awareness how ecosystem goods and services are flowing across systems while meeting demands and educating on precious biological resources. In addition, the maps could be fully utilized in rural planning, efficiently using resources and land use optimisation. In this context, reliable, best and robust sources of data are needed. National sample surveys, country wide data bio-geo resources and remote sensing based digital could be useful for scaling from local to regional and regional to global scales. The available digital data sets including census data, resource maps *viz*., forest cover, agriculture, hydro-geological, grass lands, households, water bodies, wild life, minerals etc. from different sources can be effectively used (TEEB 2010). The biophysical and socio-economic indicators are used to assess the health of rural ecosystems and also progression with the implementation of managerial interventions. The biodiversity management committee and public biodiversity register at each village level help in identifying bio resources and the different kinds of services for the benefit of communities.

Mapping provisioning ES could be done from secondary statistical sources and data corresponding to consumption of water, yield of timber, crop, and fish harvests and consumption of livestock products. This can be measured using field data and geospatial tools, where spatial data could be geo-tagged to represent in the form of geospatial data layers. The maps of land use/land cover, watershed, cadastral and

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topographic features can be exploited to estimating provisioning ecosystem services (Grafius et al. 2016).The ecosystem service mapping essentially involve choosing an indicator to quantify specific service, thereafter collecting spatial and attribute input data, iterate the model to estimate the service; and finally, refining the model to yield fine results.

Regulating services are commonly mapped by employing suitable biophysical models. Ecosystem process models, species distribution, water and air quality models are few examples. Such kind of models simulates the rate and exchange of materials in between and across the ecosystems includes the cycling of C, N, other elements, water or pollutants through the ecosystems and the environment. These models can yield inference values for regulating a specific ES. The deterministic, stochastic, simulation and real world models are increasingly employed for quantifying regulatory services.

Assessments of cultural ES are mostly confined to recreation and eco-tourism. They are mapped by physical surveys, national accounts and data collection (e.g. toll gates or entrance fees in to PAs) from other sources. The attribute on these aspects data conjunctively used with spatial data to determine the nature of service and understand how ecosystems delivering services of recreation and tourism.

As the monitoring and mapping is indispensable for stakeholders like rural people, policy makers, and business communities to evolve decisions to create win-win situations for conserving biodiversity and ecosystems services. The services of ecosystem mapping have become more relevant tools for sustainable decision making involving the stake holders. Maps can used to identify trade-offs and synergies as well as recognize spatial mismatches between supplies, flow and demand of different ecosystem services. Furthermore, the flows of services between ecosystems and source-sink dynamics can be portrayed (Power 2010). On the basis of this information, supply and demand budgets of services can be calculated at varying patio-temporal scales. It will help in accounting the reliance of a region on ecosystem service imports or its potential to export of certain goods and services. Although better potential of ecosystem service maps in sustainable decision-making for wellbeing of societies, there is also possibility in criticizing the use of maps for further exploitation of natural resources, promoting land transformations or supporting illegal encroachment activities. Therefore, the maps need to be carefully documented without any bias with the best knowledge available.

5. **Synergies and Trade-offs policy framework for Biodiversity Conservation and Ecosystem Services**

There are great synergies exist between ecosystem services and bio resource conservation. Nevertheless, there are also numbers of asymmetries that make synergies hard to achieve simultaneously. The protection of biodiversity and rejuvenation of ecosystem services must be on place, considering the different human activities, those rapidly transforming rural socio-ecological conditions.Ecosystem services are now included in policy targets and making suitable decisions on natural resources, while considering harsh trade-offs and synergies (Power 2010). The bottleneck is to evolve robust indicators to quantify

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ecosystem services to assess the current demand and supply with future direction. Human exploitation of ecosystem services is most likely to further increase with growth human population and expansion of consumption. The increase in life expectancy and reduction in poverty in rural areas in last few decades had accelerated the anthropogenic activities that enhanced the certain essential provisions at the cost of regulatory and supporting services. The decline of these services is posing threats on failure of functioning of ecosystems (Rodrguez et al. 2006). There are clear-cut evidences that increasing unfavorable conditions in near future, if society could take steps to combat the adversities (TEEB 2010).

Power (2010) emphasized the importance of understanding trade-offs and synergies among ecosystem services and biodiversity, thereby ensuring multiple services without compromising with much needed provisions. Analysing trade-offs is critical for evolving 'win-win' solutions that could lead to biodiversity conservation simultaneously supporting socio-economic development. The intensification of trade-offs with declining services are rather difficult to achieve in areas subjected those rural areas under severe biotic stress (Rodrguez et al. 2006).Trade-offs is also significant component of the ecosystem service framework; what service will be fostered compromising with other service. Analysing past trends in the rural areas show trade-offs between provisioning and supporting services resulted in increase in the former and decline in latter services (MEA 2005).

The problems and trade-offs between growth and healthy environments have been studied from a variety of theoretical perspectives, including environmental entitlements, the commons impasse, and the evolution of natural capital-based livelihoods. In the last century, inclusive policies on the green revolution and agriculture tackled poverty, lifestyles, and food security in developing countries **(**Hayami and Kikuchi 1999), while also placing pressure on resources. The relationship between poor, natural resource-dependent people and their environment is well known. Entitlement theory, political ecology, resilience theory, social vulnerability, and govern mentality are just a few of them.

The policies incorporating socio-ecological framework with nature based solutions and bottom up management approaches deliver both good and incentives for minimizing the damages of environmental degradation and ensure the holistic development of ecosystems and rural communities. For e.g. policies which address trading of nutrient schemes can be pursued at local levels to reduce water and air pollution. Trading of C, $NO_2$and S shall be another area directly benefits the communities and increase the additional income to offset these emissions (DePiperet al. 2016).

Further, there are possibilities in streamlining the precious service values with ecosystems management approach and policies must aimed at smart, inclusive and holistic development aligning with targets of Sustainable Development Goals lead to prosperity and sustainability. Linking services to certification schemes together with jurisdictional management and regulatory policies foster the direct delivery of benefits while controlling negative effects (Alleway et al. 2018).

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Payments for ecosystem services to rural communities for conservation activities such as C sequestration, hydrological services, soil erosion, and protection of over grazing, fire hazards, habitat soil conservation are in vogue as part of commitments to international agreements for conservation of natural ecosystems and environmental development. The incentives offered to societies to exchange for managing ecological services. PES is now publicized as a tool for rural development (Brockerhoff et al. 2017). The programs involve agreement between consumers and the suppliers of services. However, the many schemes are public funded extended by governments and occasionally involving working in this direction. The community rendering the services uphold the wholesale rights and supply flow of benefits to the consuming party in lieu of payments of services, while in the case of private firms; the agreement is between communities and companies. The supplier of ecosystem services generally willing to accept a greater payment than cost of providing the services. Many countries are encouraging the farmers through green bonus in rural areas for protecting natural ecosystems and balancing ecosystems and communities. The CDM mechanism and REDD+ are some good examples where the people are financially benefitted by extending climate regulation services through developing C pools in agricultural and degraded forest landscapes (Howe et al. 2014). The payments are made as per the criteria on the basis of emission reduction units traded in the form of C credits in national and global markets. There are quite few examples of payments for services encouraging farmers for green development using nature based solutions (Adams et al. 2018). China is paying to rural communities for ecosystem services towards the practice of forestry and agroforestry on upper catchment of rivers for controlling floods and soil erosion. Likewise USA, Cost Arica, Brazil, India, Nepal, Kenya, Philippines, many European and American countries have vigorously started programs for paying for many ecosystem services. Out of twenty four ecosystem services identified by MEA, only the three services related to water shed development, climate change mitigation and biodiversity conservation have received tremendous attention and provided with large economic benefits. However, many of the ecosystems services have not received adequate attention and the benefits accrued are only meager and proxy in satisfying the growing needs of rural societies (Kanungwe et al. 2013). Further, the sharing of equitable benefits of bio resources and services among communities and industries are still unfair discouraging the conservation of biodiversity and ecosystem services by many rural communities. Therefore, it is essential to revise the policies, formulating norms for strengthening local governance, banking, insurance and financial facilities so that rural people, who are the real custodians of nature and natural ecosystems actively participate in effectively manage biological resources and enhancing multiple ecosystem services (Xiao et al. 2019). There is growing need for strengthening education, awareness, health, capacity building and encouraging community based management for improving rural livelihoods and sustainable development.

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6. Sustainable Development Goals –Ecosystem Service in rural landscapes - A way forward

Sustainable development is ecologically, economically, environmentally and socially balanced development aims at fulfilling the needs of present generation without compromising the future generation. The harmony and balance must be maintained between utilization of natural resources and socio-economic development without damaging biodiversity and ecosystem services, which are key for sustainable rural livelihoods (Jost 2007). Sustainable development goals (SDG), 2015 are evolved to address global challenges of environment and human wellbeing. Of seventeen goals, of which 6, 13, 14 and 15 goals are directly related to biodiversity and water ecosystem services, while other goals are indirectly related to these aspects. The SDG goals are interconnected and achievement could be realized only by taking on account of all ecosystems and resources including land air and water. Ecosystems and socio-ecological approaches needs to be integrated for better planning, policy development and decision making for building resilience among rural communities (Irvine et al 2019). How different ecosystems contribute for the socio-economic development of rural communities is critical for long term biodiversity protection and sustainable use of ecosystems. The eradication of poverty, unemployment, hunger, and malnutrition and ecosystem stability could be attained by adopting holistic developmental pathway, which needs strong policies and developmental programmes and mission mode projects. Mainstreaming of biodiversity into different economic activities is considered necessary to both halt biodiversity loss and achieves the SDGs, evolve interlinkages between biodiversity and human health. A conceptual frame work of interlinking biodiversity - ecosystem services – SDG is essential, where the synergies and trades offs could be identified with the site specific targets and monitoring indicators to evolve innovative solutions that match socially-ecologically engineered no one leave behind to achieve the expected targets. However, such policy formulation is very complex in accounting the social, economic and environmental challenges simultaneously for achieving endeavours of SDG-2030.

7. Conclusions

Continuous access to ecosystem services from prevailing biodiversity are critical for sustaining livelihoods, economy and well-being of population living in rural landscapes. However, there is growing concern over in increase in anthropogenic disturbances resulting in loss of biodiversity and disrupting the ecosystem services in many rural areas. The boundless greediness, voracious demands and selfishness negative activities are modifying ecosystems and degenerating provisioning, regulatory, supporting and socio-cultural ecosystem services in rural areas. The burgeoning population and global climate changes further aggravating the multipronged problems in rural areas, rapidly transforming structure and functioning of socio-ecological systems.

Addressing the decline in ecosystem services and eroding biodiversity in rural areas both in scale and scope needs many possible means to fit the diverse political, economic, cultural, climatic, geographical and ecological conditions. Therefore,

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mainstreaming of biodiversity conservation along with improving ecosystem services is essential to meet the demands of environmental and socio-cultural needs and also help in eradicating poverty, unemployment and livelihoods in rural communities. The socio-ecological approaches interlinked with sustainable management of ecosystems involving the participation of locales needs are advocated. Eventually, the plan and usage of a biologically rich ecosystems will require a boundless appropriation of new perspectives and social mentalities that depend on natural and environmental morals, which incorporate thought for the necessities of people in the future of individuals just as different species and common biological systems. This will be the most ideal method of managing the supposed "ecological emergency," a cutting edge wonder that is related with quick populace development, asset consumption, and natural harm. Mapping of ecosystem services and indicators at varying spatial scales are essential to determine the status and understand the possible reasons for degradation and loss of biodiversity. Reinforcing the inherent link between ecosystems and societies with harmonious living with nature will be able to bring resilience and restore degraded ecosystems in rural landscapes. Innovative policies and programmes must be reinvigorated and implemented to conserve biodiversity along with improving ecosystem services for improving green economy. The monetary benefits shall be provided in the form of incentives to rural people in maintaining habitability of ecosystems and continuous supply of ecosystem services. The trade-offs between ecosystem services across time and space, affecting the provision of benefits taken in to cognition. The synergies and trade-offs in conserving biodiversity and development and nexus in food-energy water related ecosystem services must be addressed in action plans and schemes to be implemented in rural areas The ecosystem services-biodiversity conservation needs to be on top priority in agenda of developmental plans in rural landscapes for achieving targeted sustainable development goals (SDG) by 2030.

References

1. Adams, H., Adger, W.N., Nicholls, R.J. (2018). Ecosystem Services Linked to Livelihoods and Well-Being in the Ganges-Brahmaputra-Meghna Delta, *Ecosystem Services for Well-Being in Deltas*, pp. 29-47.
2. Aerts, R., Honnay, O. (2011) Forest restoration, biodiversity and ecosystem functioning. *BMC Ecol*, pp. 11-29.
3. Alamgir, M., Turton, S.M., Macgregor, C.J., Pert, P.L. (2016). Assessing regulating and provisioning ecosystem services in a contrasting tropical forest landscape, *Ecol Indic*, vol. 64, pp. 319–334.
4. Alleway, H.K., Gillies, C.L., Melanie, J., Bishop, R.R., Gentry, S.J., Jones, R. (2018). The Ecosystem Services of Marine Aquaculture: Valuing Benefits to People and Nature, *Bioscience*, pp. 1-10.
5. Barlow, J. (2016). Anthropogenic disturbance in tropical forests can double biodiversity loss from deforestation, *Nature*, vol. 535, pp. 144–147.
6. Barnosky, A.D., Matzke, N., Tomiya, S., Wogan, G.O.U., Swartz, B., Quental, T.B., Marshall, C., McGuire, J.L., Lindsey, E.L., Maguire, K.C., Mersey, B. &Ferrer, E. A. (2011). Has the Earth's sixth mass extinction already arrived? *Nature*, vol. 471 (7336), pp. 51–57.

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online): 0493-2137
E-Publication: Online Open Access
Vol:54 Issue:07:2021
DOI 10.17605/OSF.IO/95YEU

7. Tripathy, B. Tripathy, P., Sahu, P., **Rout** S. and Sindhu, M.S. (2020). Bio fortification of Vegetable Crops - A New Tool to Alleviate Micronutrient Malnutrition. Agriculture and Rural Development: Spatial Issues, Challenges and Approaches. Pp. 83-97. ISBN 978-81-946685-8-9.
8. Beer, C., Reichstein, M., Tomelleri, E., Ciais, P., Jung, M., Carvalhais, N., Rödenbeck, C., Arain, A., Baldocchi, D., Bonan, G., Bondeau, A., Cescatti, A., Lasslop, G., Lindroth, A., Lomas, M., Luyssaert, S., Margolis, H., Oleson, K., Roupsard, O., Veenendaal, E., Viovy, N., Williams, C., Woodward, I., Papale, D. (2010). Terrestrial gross carbon dioxide uptake: global distribution and covariation with climate, *Science*, vol. 329, pp. 834–838.
9. Belton, B., Bush, S.R., Little, D.C. (2018). Not just for the wealthy: Rethinking farmed fish consumption in the Global South, *Global Food Security,* vol. 16, pp. 85–92.
10. Benkendorff, K. (2009). Aquaculture and the production of pharmaceuticals and nutraceuticals. pp. 866–891 in Burnell GM, Allan G, eds. New Technologies in Aquaculture. Woodhead Publishing Limited.
11. Bregman, T.P., Lees, A.C., Seddon, N., Macgregor, H.E.A., Darski, B., Aleixo, A., Bonsall, M.B., Tobias, J.A. (2015). Species interactions regulate the collapse of biodiversity and ecosystem function in tropical forest fragments, *Ecology*, vol. 96(10), pp. 2692–2704.
12. Brockerhoff, E.G., Barbaro, L., Castagneyrol, B., Forrester, D.I., Gardiner, B., González-Olabarria, J.R., Lyver, P.O., Meurisse, N., Oxbrough, A., Taki, H., Thompson, I.D., van der Plas, F., Jactel, H. (2017). Forest biodiversity, ecosystem functioning and the provision of ecosystem services, *Biodiver sConserv*, vol. 26(13), pp. 3005–3035.
13. Bullock, C., Joyce, D., Collier, M. (2018). An exploration of the relationships between cultural ecosystem services, socio-cultural values and well-being, *Ecosyst. Serv*, vol. 31, pp. 142–152.
14. Carpenter, S.R., Mooney, H. A, Agard, J., Capistrano, D., Defries, R.S., Díaz, S., Dietz, T., Duraiappah, A.K., Oteng-Yeboah, A., Pereira, H.M., Perrings, C., Reid, W. V, Sarukhan, J., Scholes, R.J. (2009). Science for managing ecosystem services: Beyond the Millennium Ecosystem Assessment, Proceedings of the National Academy of Sciences of the United States of America, vol. 106 (5), pp. 1305–1312.
15. Chivian, E., Bernstein, A.S. (2004). Embedded in nature: Human health and biodiversity, *Environ Health Perspect*, vol. 112, pp. A12–A13.
16. Clark, M. and Tilman, D. (2017). Comparative analysis of environmental impacts of agricultural production systems, agricultural input efficiency, and food choice, *Environmental Research Letters*, vol. 12(6), pp. 6-16.
17. Costanza, R., d'Arge, R., de Groot,R., Farber, S., Grasso, M., Hannon,B., Limburg, K.,Naeem,S., O'Neill,R.V., Paruelo,J.,Raskin, R.G.,Sutton,P.,vandenBelt,M. (1997).The value of the world's ecosystem services and natural capital, *Nature*, vol. 387, pp. 253–260.
18. Costa-Pierce, B.A., Bridger, C.J. (2002). The role of marine aquaculture facilities as habitats and ecosystems. pp. 105–144 in Stickney RR, McVey JP, eds. Responsible Marine Aquaculture. CABI International.

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online): 0493-2137
E-Publication: Online Open Access
Vol:54 Issue:07:2021
DOI 10.17605/OSF.IO/95YEU

19. Daily, G.C., Ehrlich, P.R. (1995). Population diversity and the biodiversity crisis. In: Perrings C, Maler K, Folke C, Holling C, Jansson B (eds) Biodiversity conservation: problems and policies. Kluwer Academic Press, Dordrecht, pp 41–51.
20. Daily, G.C., Matson, P.A. (2008). Ecosystem services: From theory to implementation, *ProcNatlAcadSci USA*, vol. 105, pp. 9455– 9456.
21. Davis, A.Y., Lonsdorf, E.V., Shierk, C.R., Matteson, K.C., Taylor, J.R., Lovell, S.T., Minor, E.S. (2017). Enhancing pollination supply in an urban ecosystem through landscape modifications, *Landsc. Urban Plan*, vol. 162, pp. 157–166.
22. deBello,F.,Lavorel,S.,Diaz,S.,Harrington,R.,Cornelissen,J.,Bargett,R.,Berg,M.,Cipriotti,P.,Feld,C.K.,Hering,D.,MartinsdaSilva,P.,Potts,S.,Sandin,L.,Sousa,J.P.,Storkey,J., Wardle,D.,Harrison,P.A. (2010). Towards an assessment of multiple ecosystem processes and services via functional traits, *Biodivers. Conserv*, vol.19, pp. 2873–2893.
23. dePiper, G.S., Lipton, D., Lipcius, R.N. (2016). Valuing Ecosystem Services: Oysters, Denitrification, and Nutrient Trading Programs, *Marine resource economics*, vol. 32(1). Pp. 000-000.
24. Díaz, S., Fargione, J., Chapin, F.S., Tilman, D. (2006). Biodiversity loss threatens human well-being, *PLoS Biology*, vol. 4 (8), pp. 1300–1305.
25. Dinerstein, E., Varma, K., Wikramanayake, E., Powell, G., Lumpkin, S., Naidoo, R. (2013). Enhancing conservation, ecosystem services, and local livelihoods through a wildlife premium mechanism, *Conservation Biology*, vol. 27, pp. 14–23.
26. Rout, D. S., Prusty, A. K., Tarania, P. R. and Rout, S. (2020). Participation of Rural Youth in Agriculture and Allied Activities-A Review, *Akshar Wangmay*, Special Issue, Volume-I, pp. 32-34.
27. EEA. (2015). European Ecosystem Assessment – Concept, Data and Implementation Draft, Brussels EEA, pp. 1–70.
28. Fernandes, G.W. (2017). Dismantling Brazil's science threatens global biodiversity heritage, *Perspect. Ecol. Conserv*, vol. 15, pp. 239–243.
29. Gamfeldt, L., Snall, T., Bagchi, R., Jonsson, M., Gustafsson, L., Kjellander, P. (2013). Higher levels of multiple ecosystem services are found in forests with more tree species, *Nature Commun*, vol. 4, pp. 1340.
30. Gaucherel, C., Pommereau, F. (2019). Using discrete systems to exhaustively characterize the dynamics of an integrated ecosystem, *Methods Ecol. E*, vol. 10, pp. 1615–1627.
31. Golden, C.D., Bonds, M.H., Brashares, J.S., RodolphRasolofoniaina, B.J., Kremen, C. (2014). Economic valuation of subsistence harvest of wildlife in Madagascar, *ConservBiol*, vol. 28(1), pp. 234–243
32. González, E., Salvo, A., Valladares, G. (2015). Sharing enemies: evidence of forest contribution to natural enemy communities in crops, at different spatial scales, *Insect conservation and Diversity*, vol. 8(4), pp. 359–366.
33. Dash, G. P., Padhiary, A. K., Rout, S., Prusty, A. K. and Pradhan, K. (2020). Rural Marketing- An Overview, *Akshar Wangmay*, Special Issue vol. 1, pp. 35-38.
34. Grabowski, J.H., Brumbaugh, R.D., Conrad, R.F., Keeler, A.G., Opaluch, J.J., Peterson, C.H., Piehler, M.F., Powers, S.P., Smyth, A.R. (2012). Economic valuation of ecosystem services provided by oyster reefs, *BioScience*, vol. 62, pp. 900–909.

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online): 0493-2137
E-Publication: Online Open Access
Vol:54 Issue:07:2021
DOI 10.17605/OSF.IO/95YEU

35. Grafius, D.R., Corstanje, R., Warren, P.H., Evans, K.L., Hancock, S., Harris, J.A. (2016). The impact of land use/land cover scale on modelling urban ecosystem services, *Landsc. Ecol*, vol. 31, pp. 1509–1522.
36. Hayami, Y. and Kikuchi, M. (1999). The Three Decades of Green Revolution in a Philippine Village, *The Japanese Journal of Rural Economics*, vol. 1, pp. 10-24.
37. Howe, C., Helen, S., Vira, B., Mace, G.M. (2014). Creating win-wins from trade-offs? Ecosystem services for human well-being: a meta- analysis of ecosystem service trade-offs and synergies in the real world, *Glob Environ Change*, vol. 28, pp. 263–275.
38. IPBES. (2016). Summary for policymakers of the methodological assessment of scenarios and models of biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, In S. Ferrier, K. N. Ninan, P. Leadley, R. Alkemade, L.A. Acosta, H. R. Akçakaya, L. Brotons, W. Cheung, V. Christensen, K. A. Harhash, J. Kabubo-Mariara, C. Lundquist, M. Obersteiner, H. Pereira, G. Peterson, R. Pichs-Madruga, N. H. Ravindranath, C. Rondinini, B. Wintle (Eds.). Secretariat of the intergovernmental science-policy platform on biodiversity and ecosystem services (pp. 1–32). Germany:Bonn. ISBN: 978-92-807-3570-3.
39. Irvine, K.N., Hoesly, D., Bell-Williams, R., Warber, S.L. (2019). Biodiversity and spiritual well-being. In: Marselle, M.R., Stadler, J., Korn, H., Irvine, K., Bonn, A. (Eds.), Biodiversity and Health in the Face of Climate Change. Springer International Publishing, pp. 213–247.
40. Isbell, F., Tilman, D., Polasky, S. &Loreau, M. (2015). The biodiversity-dependent ecosystem service debt, *Ecology Letters*, vol. 18 (2), pp. 119–134.
41. Jacobi, C.M., doCarmo, F.F., de Campos, I.C. (2011). Soaring extinction threats to endemic plants in Brazilian metal-rich regions, *Ambio*, vol. 40, pp. 540–543.
42. Jost, L. (2007). Partitioning diversity into independent alpha and beta components, *Ecology*, vol. 88, pp. 2427– 2439.
43. Kanungwe, F.K., Quinn, C.H., Dougill, A.J. (2013). Contribution of forest provisioning ecosystem services to rural livelihoods in the Miombo Woodlands of Zambia, *Popul Environ*, vol. 35, pp. 159–182.
44. Karp, D.S., Mendenhall, C.D., Callaway, E., Frishkoff, L.O., Kareiva, P.M., Ehrlich, P.R., Daily, G.C. (2015). Confronting and resolving competing values behind conservation objectives, *PNAS*, vol. 112(35), pp. 11132–11137.
45. Kreye, M.M., Adams, D.C., Escobedo, F.J. (2014). The value of forest conservation for water quality protection, *Forests*, vol. 5(5), pp. 862–884.
46. Lal, R., Lorenz, K. (2012). Carbon sequestration in temperate forests, In: Lal R, Lorenz K, Hüttl R, Schneider B, von Braun J (eds) Recarbonization of the biosphere. Springer, Amsterdam Laurance WF. 2004 The perils of payoff: corruption as a threat to global biodiversity, *Trends Ecol. E*, vol. 19, pp. 399–401.
47. Lescourret, F. et al. (2015). A social–ecological approach to managing multiple agro-ecosystem services, *Current Opinion in Environmental Sustainability*, vol. 14, pp. 68–75.
48. MartínezPastur, G., Peri, P.L., Lencinas, M.V., GarcíaLlorente, M., Martín López, B. (2016). Spatial patterns of cultural ecosystem services provision in southern Patagonia, *LandscEcol*, vol. 31, pp. 383–399.

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online): 0493-2137
E-Publication: Online Open Access
Vol:54 Issue:07:2021
DOI 10.17605/OSF.IO/95YEU

49. Martins, K.T., Gonzalez, A., Lechowicz, M.J. (2015). Pollination services are mediated by bee functional diversity and landscape context, AgricEcosyst Environ, vol. 200, pp.12–20.
50. McLaughlin, A. and Mineau, P. (2005). The impact of agricultural practices on biodiversity, *Agriculture, Ecosystems and Environment*, vol. 55, pp. 201-212.
51. Millennium Ecosystem Assessment Panel (MEA). (2005). Island press. Washington, USA Myers N (1996) Environmental services of biodiversity, *PNAS*, vol. 93(7), pp. 2764–2769.
52. Minayeva,T.Y., Bragg, O.M., Sirin, A.A. (2017). Towards ecosystem-based restoration of peatland biodiversity, *Mires Peat*, pp. 1–36.
53. Mori, A.S., Kenneth, P., Lertzman, Gustafsson, L. (2017). Biodiversity and ecosystem services in forest ecosystems: a research agenda for applied forest ecology, *J ApplEcol*, vol. 54, pp. 12–27.
54. Pan, Y., Birdsey, R.A., Fang, J., Houghton, R., Kauppi, P.E., Kurz, W., Phillips, O., Shvidenko, A., Lewis, S., Canadell, J., Ciais, P., Jackson, R., Pacala, S., McGuire, D., Piao, S., Rautiainen, A., Sitch, S., Hayes, D. (2011). A large and persistent carbon sink in the world's forests, *Science*, vol. 333, pp. 988–993.
55. Peres, C.A., Emilio, T., Schietti, J., Desmoulière, S.J.M., Levi, T. (2016). Dispersal limitation induces long-term biomass collapse in overhunted Amazonian forests, PNAS, vol. 113(4), pp. 892–897.
56. Peri, P., Dube, F., Varella, A. (2016). Silvopastoral systems in southern South America. Springer, *Series: Advances in agroforestry*, vol. 11, Amsterdam.
57. Persha, L., Agrawal, A., Chhatre, A. (2011). Social and Ecological Synergy: Local Rulemaking, Forest Livelihoods, and Biodiversity Conservation, *Science*, vol. 331, pp. 1606–1608.
58. Polasky, S., Tallis, H., Reyers, B. (2015). Setting the bar: standards for ecosystem services, *Proc. Natl. Acad. Sci*, vol. 112 (24), pp. 7356–7361.
59. Poorter, L.,Van der Sande, M. T., Thompson, J., Arets, E.J.M.M., Alarcon,A., Alvarez-Sanchez, J. et al. (2015). Diversity enhances carbon storage in tropical forests, *Glob EcolBiogeogr*, vol. 24, pp. 1314–1328.
60. Power, A.G. (2010). Ecosystem services and agriculture: tradeoffs and synergies, vPhilos Trans R SocLond B BiolSci, vol. 365(1554), pp. 2959–2971.
61. Prusty, M., Ray, M. and Sahoo, G.R. (2020). Carbon Sequestration - A Way to Mitigate Green House Effect, *Global Environmental Governance, Policies and Ethics*, pp. 32-43.
62. Quintas-Soriano, C., Martín-López, B., Santos-Martín, F., Loureiro, M., Montes, C., Benayas, J., García-Llorente, M. (2016). Ecosystem services values in Spain: a meta-analysis, *Environ Sci Policy*, vol. 55(01), pp. 186–195.
63. Reis, L.C., Hibbeln, J.R. (2006). Cultural symbolism of fish and the psychotrophic properties of omega-3 fatty acids, *Prostaglandins, Leukotrienes and Essential Fatty Acids*, vol. 75, pp. 227–236.
64. Rissman, A.R., Gillon, S. (2017). Where are ecology and biodiversity in social-ecological systems research? A review of research methods and applied recommendations, *Conserv. Lett*, vol. 10, pp. 86–93.
65. Rodriguez, J.P. et al. (2006). Trade-offs across space, time, and ecosystem services, *EcolSoc*, vol. 11(1), pp. 14.

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online): 0493-2137
E-Publication: Online Open Access
Vol:54 Issue:07:2021
DOI 10.17605/OSF.IO/95YEU

66. Sahoo, G.R., Prusty, M., Ray, M. (2020). Ecological role and Importance of Biodiversity in Agroecosystems, *Global Environmental Governance, Policies and Ethics*, pp. 71-83.
67. Sahoo, G.R., Wani,A.M., Satpathy, B., Rout, S. (2020). Agriculture and Rural Development for Sustainability. *Agriculture and Rural Development: Special Issues, Challenges and Approaches*, Pp. 75-82.
68. Sun, G. and Vose, J.M. (2016). Forest management challenges for sustaining water resources in the Anthropocene, *Forests*, vol. 7(3), pp. e68.
69. Tallis, H., Mooney, H., Andelman, S., Balvanera, P., Cramer, W., Karp, D., et al. (2012). A global system for monitoring ecosystem service change, *BioScience*, vol. 62, pp. 977–986.
70. TEEB. (2010). 'The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations'. Edited by Pushpam Kumar. Earthscan, London and Washington.
71. Thompson, A.J., Stow, A.J., Raftos, D.A. (2017). Lack of genetic introgression between wild and selectively bred Sydney rock oysters *Saccostreaglomerata*. *Marine Ecology Progress Series*, vol. 570, pp. 127–139.
72. Thurstan, R.H., Brittain, Z., Jones, D.S., Cameron, E., Dearnaley, J., Bellgrove, A. (2018). Aboriginal uses of seaweeds in temperate Australia: An archival assessment, *Journal of Applied Phycology*, vol. 30, pp.1821–1832.
73. Wani, A.M. and Sahoo, G.R. (2020). Forest Ecosystem Services and Biodiversity. Spatial Modeling in Forest Resources Management, Environmental Science and Engineering, *Springer International Publishing*, 529-552.
74. Xiao, H., McDonald-Madden, E., Sabbadin, R., Peyrard, N., Dee, L.E., Chades, I. (2019). The value of understanding feedbacks from ecosystem functions to species for managing ecosystems, *Nat. Commun*, vol. 10, pp. 3901.