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Ecosystem Services of Bamboo

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Abstract: ***According to the Millennium Ecosystem Assessment (2002) there are four types of Ecosystem Services, i. e. (i) provisioning services; (ii) regulating services; (iii) habitat services; and (iv) cultural services. Bamboo forests provided various goods and services that promote human well - being are regarded as ecosystem services (ES); these provide landscape restoration, prevention of soil and sediment loss, food supply, domestic and industrial raw materials, and carbon sequestration Bamboo forests provide various ES that generate sociocultural, economic and ecological values and services to local and global stakeholders. They are socio - culturally connected with forest and people, produce raw materials for economic activities with local and industrial applications and provide ecological benefits to communities both in and beyond local areas.***

Keywords: provisioning services: regulating services; habitat services; cultural services

Bamboo is a fastest growing grass species and is an important forest type in the tropical and subtropical regions of Africa, Asia, and Central and South America (Lobovikov et al.2007; Buckingham et al.2014; Troy Mera and Xu 2014). Bamboo is an important non - timber forest product (NTFP) and an integral part of forestry, but it is also widespread outside the forests, including on farmlands, riverbanks, roadsides and urban areas (Lobovikov et al.2007). Although forest areas have drastically decreased in many countries, bamboo forests have progressively increased globally (Lei 2001; Zhou et al.2005; Buckingham et al.2014). Bamboo forests, including both natural and planted ones, cover 31.5 million ha (FAO 2010). These bamboo forests are valuable assets which not only support poverty reduction and economic development but also contribute to environmental conservation (Effah et al.2014; Phimmachanh et al.2015). With this, the image of bamboo forests is quickly changing from 'poor people's trees' to high - tech industrial raw materials that can be used to replace the timber and other raw materials taken from natural and planted forests (Lobovikov et al.2007; 2009). While raw material supply from forests is decreasing, bamboo can meet demands for raw material at a global scale.

Bamboo forests provided various goods and services that promote human well - being are regarded as ecosystem services (ES); these provide landscape restoration, prevention of soil and sediment loss, food supply, domestic and industrial raw materials, and carbon sequestration (Zhou et al.2005; Yiping et al.2010; Sohel et al.2015). Many studies show that bamboo is also important for restoration of degraded lands that play a key role in achieving recently adopted global restoration targets. Targets include the Bonn Challenge (to restore 150 million ha of degraded and deforested land by 2020), the New York Declaration on Forests (to restore 350 million ha by 2030) (Jacobs et al.2015; Paudyal et al.2017; Reij and Winterbottom 2017), the Great Green Wall Initiative1, Land Degradation Neutrality and Sustainable Development Goals (Wood et al.2018).

Ecosystem services from bamboo forests have been intimately associated with human well - being since time immemorial (Bajracharya et al.2013). In developing countries, bamboo is an important component of the rural farming system and plays a critical role in the rural economy, helping to sustain the livelihoods of rural people. Bamboo enterprises are the primary source of subsistence livelihoods and a source of economic upliftment for poor and underprivileged people (Lobovikov et al.2009; Nath et al.2015; Hogarth and Belcher 2013; Partey et al.2017). Bamboo also provides numerous environmental services. For example, it protects traditional houses from strong winds, and fulfils the requirements for house construction materials and fuelwood purposes (Nath et al.2015, 2015; Partey et al., 2017).

Besides contributing to local economies and the environment, global bamboo industries have rapidly developed in recent years and contributed more than USD 60 billion annually (INBAR 2019), proving that bamboo forests have the potential to contribute to inclusive and green economic development at regional and global levels (Lobovikov et al.2007; INBAR 2019). Bamboos are the world's most traded NTFPs, and have become central to emerging economies around the globe, especially in tropical regions (INBAR 2006; Lobovikov et al. 2007). Bamboos are fast growing and a sustainable wood alternative, have a high potential for carbon sequestration and are viable resources for poverty alleviation and climate change adaptation (Lobovikov et al.2007; Liese, 2009). Furthermore, bamboo is important for the rehabilitation of degraded land, as a timber substitute, for erosion control and watershed protection (INBAR 2006). With its fast growth rate and high annual regrowth after harvesting, bamboo forests have a high carbon stock potential (Yiping et al.2010), especially when the harvested culms are used as durable products (Nath et al.2015).

Ecosystems and Biodiversity which defines ES as the direct and indirect contributions of ecosystems to human well - being (TEEB 2010). This definition is also based on the definition of the ES by Millennium Ecosystem Assessment

(MEA), but we have used a slight modification, especially as regards the classification of ES. For example, supporting services in MEA is replaced by habitat services, primarily to avoid any double - counting in the ES audit (Baral et al.2016).

Bamboo forests provide various ES (Shinohara et al.2014) that generate sociocultural, economic and ecological values and services to local and global stakeholders. They are socio - culturally connected with forest and people (e. g. having spiritual significance for local communities), produce raw materials for economic activities with local and industrial applications (e. g. timber, housing, biofuel and crafts) and provide ecological benefits to communities both in and beyond local areas (e. g. carbon stock/sequestration).

According to the Millennium Ecosystem Assessment (2002) there are four types of Ecosystem Services, i. e. (i) provisioning services which include tangible benefits such as raw materials, pulp, food and biomass - based energy; (ii) regulating services, which would bring benefits in the form of increased water infiltration, reduced erosion and climate regulation; (iii) habitat services that bring benefits to wildlife habitat and genetic diversity; and (iv) cultural services including recreation, ecotourism, education and spiritual experiences (Fig.1).

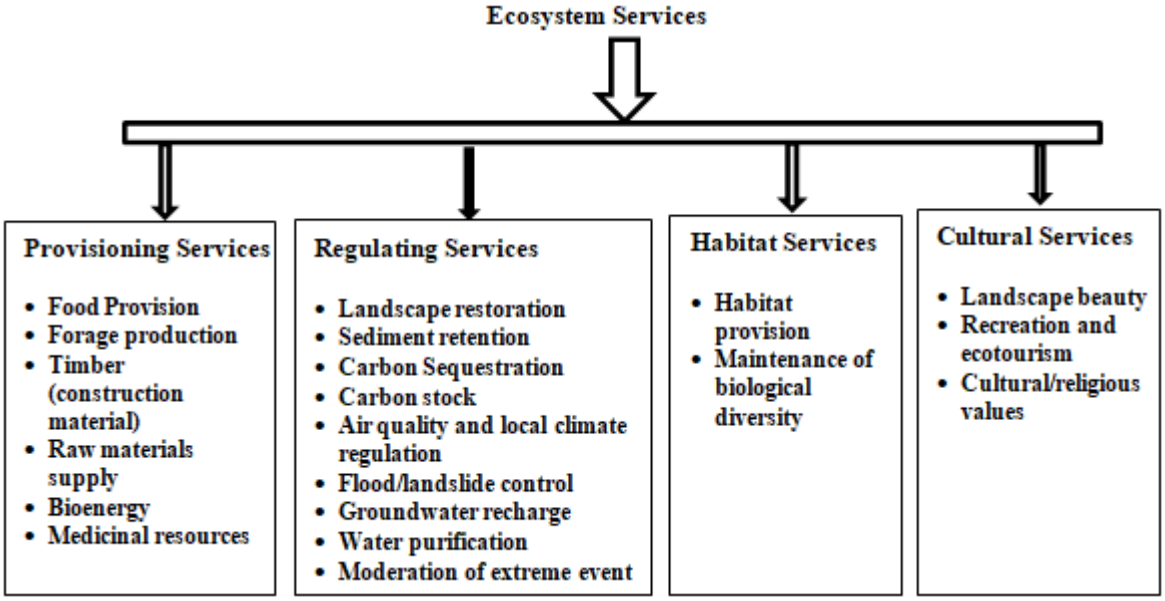

Figure 1: Ecosystem services and their links to human wellbeing (after Millennium Ecosystem Assessment 2003)

(i) **Provisioning services** which include tangible benefits such as raw materials, pulp, food and biomass - based energy.

(a) Food provision: More than 200 species of bamboos provide food (edible and palatable shoots) from wild and cultivated areas throughout the world. Bamboo shoots no doubt form an important food source from the plant origin. Consumption in various forms is evident in the north - eastern regions but it has a great potential to be incorporated in several other dishes all over the world due to its special nutritional profile. Various edible species exist in different parts of the world, which are eaten in multiple forms. Most of the studies, which have been reviewed, depict that bamboo shoots are very good reservoirs of nutrients. They are rich in protein and fibre content and low in fat content. They are good sources of vitamins like vitamin C in fermented shoots and potassium, a healthy heart mineral. In developing countries, where protein calorie malnutrition is a major problem, fermented vegetable proteins have a great potential and a ray of hope for meeting the body requirements through food supplementation.

Indicators of ES (Unit of measurement): No. of species producing edible shoots • Amount of shoot production (t ha^{-1} yr^{-1}).

(b) Forage production: Bamboo supplies forage that is popular for local livestock development everywhere. Due to its fast growth, high biomass production and wide adaptability of green leaves during winter months, bamboo can be an alternative source of fodder for dairy cattle and maintain their milk production during the dry season. Bamboo leaves are a good source of nitrogen for ruminants and may be complementary to silage in a mixed ration, without compromising the milk production. This allows cows to maintain their performance during the dry season, which is a period of forage shortage. Farmers can integrate bamboo cultivation in their forage system to enhance the feed sufficiency and diversity, in order to improve the animal productivity, as well as the food security. It is important to identify the optimal stage and period to harvest bamboo leaves, in order to reach a moderate fibre content and improve intake and digestibility. Thus bamboo could be an alternative way to increase the fodder supply for cattle.

Indicators of ES (Unit of measurement): • Amount of raw material supply (t $ha^{-1}yr^{-1}$).

(c) Timber (construction materials): Bamboo can support low - carbon and sustainable products. Bamboo has better physical (mechanical) properties than many other timber species, such as high tensile strength, high flexibility, and light weight, as a result it can replace wood, steel and concrete in many industrial applications and can be widely

used as a building material. Unlike brick and cement structures, bamboo buildings are usually cheaper, lighter, and more earthquake - resistant.

Many bamboo species provide construction timber and are used for building raw materials, modern engineered bamboo products, composite panels and boards. Engineered bamboo may well replace steel, wood and concrete in many uses. Development of bamboo resource as an alternative plant in the tropical forest will help reduce over - dependence on timber and other species which are almost depleting from the forest. Bamboo is extensively used for construction of walls and partitions. Posts and beams are the main elements normally constructed with bamboo provide structural framework for walls. They positioned in a way to be able to withstand forces of nature. An infill is used between framing elements to add strength and stability to the walls. Bamboo is one of the best roofing materials and provides ample sturdiness to the structure. It is a proven shield against forces of nature or animals and are considerably light weighted which makes them easy to install. The bamboo roofs encompass purlins, rafters and trusses**.** Due to advantageous properties of bearing heavy load bamboos are considered as one of the highly - endorsed materials for scaffolding even for tall structures. The ever - growing population and improving standards of living, are placing increasing pressure on the country's forest resources. As the most important non - wood forest product and wood substitute, bamboo is playing all increasingly important roles in reducing timber demand pressure on forest resources.

Indicators of ES (Unit of measurement): • No. timber - producing bamboo species • Amount of timber bamboo production (No. of clumps/stands per ha or t $ha^{-1}yr^{-1}$).

(d) Raw materials supply: Bamboo provides raw materials for various types of enterprises from traditional domestic to industrial uses such as different types of bamboo housing, flooring, crafts and fiber for pulp, paper and clothes.

- Paper and pulp: Bamboo is the best raw material for pulp in India. They were also used in ancient forms of paper manufacture. Till recently, almost all the paper manufactured in India was made from bamboos (mainly *Dendrocalamus strictus*). Bamboos are also used in many other processes in a paper mill.
- Woven Bamboo: Woven bamboo is used for making a large number of objects of domestic, industrial and decorative use. They are light, flexible and cheap to obtain.
- Baskets: Bamboo baskets are very widely used in India.
- Matting: Bamboo strips are readily woven into a wide variety of shapes and patterns, to be used in different ways in the rural areas in the vicinity of bamboo bearing forests and elsewhere.
- Ropes: Bamboos are widely used for making ropes in north - east India. These ropes are distinctly superior to ropes made from other fibres.
- Furniture: In many rural areas, particularly in north - east India the entire furniture of a house may be made up of bamboo. These include everything from the common stool to sofas and garden chairs. Bamboo furniture is also very popular in many urban homes.
- Bridges: In the mountainous parts of north - east India, bridges made from bamboo are common. It comprises of strong cables made of split bamboo and strung across the points to be bridges. Splints of suitable sizes may be laid across these cables keeping in view the expected weight of the load it is likely to bear.
- Transport: Bamboo rafts and poles are used for the transport of people and good from one place to another.

Indicators of ES (Unit of measurement): • No. bamboo clumps/ stands supplying raw materials • Amount of raw material supply (t $ha^{-1}yr^{-1}$) • Amount of revenue earned (USD $ha^{-1}yr^{-1}$).

(e) Bioenergy: Bamboo has traditionally been used as a source of domestic energy and substitute for wood charcoal and mineral coal. Bamboo charcoal is another important product, since it is a renewable biomass fuel that can replace wood charcoal or mineral coal. Biogas and oil can also be produced from bamboo. Bioenergy can replace fossil fuel and decrease the carbon footprints. Bamboo biomass can replace coal, either partially or completely. When the coal is replaced partly with bamboo biomass, it is cofiring of coal and bamboo, that reduces the cost, CO2 emission, SOX and NOX emission. Cofiring is sustainable and moves towards renewable energy. Bamboo biomass has good calorific value, very low ash content as compared to coal and optimum combustion property when fired along with coal. Cultivated bamboo as energy plantation and used at the age of one year, doesn't have ash deposition issues, corrosion, pollutant emission and short supply of biomass fuel. Cofiring biomass residues with coal in traditional coal - fired boilers for electricity production or in cementproduction, generally represents one of the most cost - effective and efficient renewable energy options for adoption of climate change technology, which doesn't need additional investment.

Indicators of ES (Unit of measurement): • Amount of charcoal (t $ha^{-1}yr^{-1}$) • Amount of oil production (ML $ha^{-1}yr^{-1}$) • Amount of biogas production (e. g. pallets: t $ha^{-1}yr^{-1}$ or electricity generated from bamboo gasification plants: KWh $ha^{-1}yr^{-1}$).

(f) Medicinal resources: Traditional and indigenous medicine derived from bamboo products. Several species like *Sasa borealis (Hack.), Phyllostachys edulis, Pseudosasa amabilis, Pleioblastus gramineus, Indocalamus latifolius, Phyllostachys heterocycla, Merostachys pluriflora, P. pubescens*have shown an important antioxidant potential demonstrating that they can be applied in the treatment of different diseases such as antiinflammatory, antitumor, and several other ailments involving oxidative processes. Additionally, besides the usual secondary metabolites, bamboo extracts may contain biologically active peptides and polysaccharides. The combined effect of these macromolecules with polyphenols and other metabolites may lead to multiple biological effects, such as antifree radical, antiaging, antifatigue, antibacteria, antivirus, and as a functional dietary supplement, cosmetic ingredient, and food additive.

Indicators of ES (Unit of measurement): • No. of species of medical value • Harvestable amount (tonnes $ha^{-1}yr^{-1}$)

(ii) Regulating services: which would bring benefits in the form of increased water infiltration, reduced erosion and climate regulation. Bamboo forests have an extensive rhizome system, a thick litter layer, highly elastic a culms, and dense canopy. These characteristics give bamboo forests a high capacity for erosion control, soil and water conservation, landslide prevention, protection of riverbanks, and windbreak and shelterbelt potential. Thus it would bring benefits in the form of increased water infiltration, reduced erosion and climate regulation.

(a) Landscape restoration: Restoration of degraded land through planting bamboo. Land degradation is defined as the long - term loss of ecosystem function and productivity caused by disturbances from which the land cannot recover unaided. Bamboos are known to grow in "poor soils" and therefore used for rehabilitation of degraded lands. It can be grown under diverse environmental conditions such as in full sunlight to the areas of high winds. This enables it to be used as a starting point in restoring degraded land. Adaptive capability, nutrient and water conservation of bamboo, enables it as fore - runner plants in the eco - restoration of degraded land. Because of the fast growing nature and the dense foliage of bamboos, it is able to maintain the thick layer of litter. This litter layer maintains microclimate in the understory and soil moisture, the most important factors for the restoration of degraded lands.

(b) Bamboo for Reclamation of Sodic Soil: Salinization of soils and ground water is a serious land degradation problem in arid and semi - arid areas and is increasing steadily in many parts of the world. Bio - drainage involves the planting of salt tolerant and fast transpiring trees to pump out the excess water and dissolved salts.

Bamboo plantation increases Soil Hydraulic conductivity, improves the physical properties of the soil, increases in soil organic matter content, porosity, water retention, structural stability and organic matter content of soil.

Indicators of ES (Unit of measurement): • Total restored area (ha)

(b) Sediment retention: Bamboo forests stabilize the slope and prevent soil erosion, which improves the condition of land and controls floods and landslides. These phenomena reduce the deposition load downstream. Degradation of soil due to erosion is a major threat in any ecosystem, as it reduces the sustainability and productivity. Bamboo is also well known for controlling soil erosion, as it grows and establishes itself very well on sloppy terrains, hill slopes, embankments and gullies etc. This feature is attributed due to the extensive fibrous and inter connected root system (Zhou et al.2005). The leafy mulch and the dense foliage of bamboo, protects soil against the beating and scorching actions of the raindrops. Also the year wise production of new culms from the rhizomes provides the opportunity of harvesting bamboo without affecting biomass and soil. Generally, roots and rhizomes of bamboo form a woven net in the rhizosphere which helps in holding the soil. In several studies, it has been reported that most of roots and rhizomes of bamboo are present in top layer of soil i. e.0 - 30 cm, which made it most effective in controlling soil erosion. Planting bamboo on the sides of riverbanks and streams, helps in protecting riverbanks from the erosive action of rivers as these helps in binding the soil tightly and secondly they grows well due to ample supply of moisture. Bamboo is quite effective in conserving soil erosion in ravines. Introducing bamboos in the coastal sand has been proved as an effective measure to increase tree species in coastal forest shelterbelts (Zhang et al., 2007). Bamboos were found to be suitable for increasing the overall soil fertility and preventing soil erosion. A model demonstrating intercropping of Bamboo groves with folder grass was found to be most effective in controlling soil erosion.

Indicators of ES (Unit of measurement): • Rate of downstream siltation ($tha^{-1}yr^{-1}$).

(c) Carbon sequestration: Since the industrial revolution, increasing concentration of atmospheric carbon dioxide (CO_2) is among the most significant human influences on the global climate change. The increase in atmospheric CO_2 concentration is projected to lead 1–3.5℃ global mean surface temperature by twenty first century. Carbon sequestration is one of the approaches in climate change mitigation policy that had received significant attention over the past several years. Bamboo is not only an important part of many natural and agricultural eco - systems, providing a number of ecosystem services such as food, fodder furniture, construction material, soil conservation and ecosystem stability, but also a carbon sink as well. Bamboo biomass, bamboo litter and bamboo soil acts as a carbon sink in forest ecosystem. It has been observed that bamboos can capture and sequester significant amount of atmospheric carbon and consequently help in mitigating climate change, in a similar way that forests do. If the amount of bamboo carbon fixation is larger than that of the decomposition, bamboo ecosystem is a carbon sink; otherwise it is a carbon source. Therefore, the ability of bamboo forests to sequester high amount of carbon can make the bamboo based agroforestry system a possible prototype to restore degraded forests and jhum lands on one hand and enhance sequestration of substantial amount of atmospheric carbon dioxide on the other. Sustainable utilization, conservation and proper management of bamboo forests can make it an effective carbon sink besides fulfilling the diverse needs of rural livelihoods since bamboo grows faster and can sequestrate carbon from the atmosphere at a faster rate than many tree species (Thokchom and Yadava 2015a).

Indicators of ES (Unit of measurement): • Amount of carbon sequestration annually (tonnes C $ha^{-1}yr^{-1}$ or Mg $ha^{-1}yr^{-1}$) • No. of bamboo clumps/stands per ha.

(d) Carbon stock: Global warming is one among the most devastating problems of the new millennium and Kyoto Protocol expresses the deep concern of scientific community on increasing carbon emission due to developmental activities. Being one of the most productive and fastest growing plants on the planet with its decay resistant litter, bamboo potentially acts as a valuable sink for carbon storage. On an average, one hectare of bamboo stand absorbs about 17 tonnes of carbon per year. Bamboo stands

occupy an area of 36 million hectares worldwide which is equivalent to 3.2 percent of the total forest area in the world. Increased bamboo biomass indicates a higher amount of carbon storage

Indicators of ES (Unit of measurement): • Area of bamboo forest (No. /ha) • No. of clumps/stands per ha • Amount of carbon stock/ stored (tonnes C ha^{-1}).

(e) Air quality and local climate regulation: Bamboo forests filter the air and remove odors, pollutant gases (nitrogen oxides, ammonia, sulfur dioxide and ozone) and dust particles out of the air through the action of leaves and bark. Improved air quality makes the local climate better. Bamboo stands also are known as "natural oxygen bars". The surface of a bamboo leaf is rough, and it can capture 4 to 8cm^{-2} of dust. A 40m wide bamboo belt can also reduce noise levels by 10 to 15 dB (Li et al.2015).

Bamboo can clean the CO_2 in the air, absorb the sewage water, removes heavy metals, stop soil erosion, increase water holding capacity of the soil and reduce the particle matter in air. Due to the fact that Bamboo sequester highest carbon, it cleans up the atmosphere from the CO_2 generated due to burning of non - renewable energy resources such as Coal, oil for the benefit of human kind. Bamboo has a fibrous root system that is shallow and capable of holding 200 – 400 mm of rain water. The roots are able to assimilate macro and micro nutrient from sewage water and also cleans up the heavy metals if any. Thus, Bamboo is a good scavenger crop to clean the sewage / ETP water at a low cost and adding environmental benefit such as reduction in temperature, increase in Oxygen, reduction in bad odour and reduction in Particulate Matter (2.5 PM and 10 PM). Bamboo has large quantity of leaves which is capable of reducing the urban pollution such as PM2.5, SO2, NOx, CO, CO_2, VOCs specifically from the air and at the same time produce highest quality of O_2 thus it is able to regulate particulate matter in cities.

Bamboo trees grown on the either side of the highway, acts as a natural barrier by reducing the noise and air pollution level. As bamboo is a fastest growing plant on earth, it reaches its maximum growth as "Pollution Filter" in 3 years' time while other trees would take 25 years to reach its maximum growth to act as pollution filter. Bamboo is able to adsorb PM2.5 to PM10 by the leaves ability to capture and ultimately mature leaves falls down and gets integrated into the soil (Paudyal et al.2019). Bamboo forests showed a strong reduction on Air Pollution, the concentration of atmosphere PM2.5, PM10, PAHs, VOCs decreases by bamboo in several experiments. The bamboo leaf is able to intercept PM 2.5 because of the leaf roughness, pore structure, wax content, hairy structure on the Leaf surface. This varies for different species of Bamboo due to variation in the Leaf Area Index and Surface Area Characteristics.

Indicators of ES (Unit of measurement): • Total leaf area (TLA) (TLA ha^{-1}) • Amount of pollutants absorbed by the bamboo forest (No. of pollutants).

(f) Floods/ landslides control: Bamboo forests control floods and landslides by holding soil particles together through a complex network of roots and rhizomes in the field.

Indicators of ES (Unit of measurement): • No. of events of landslides/flooding • Amount of soil loss (tonnes $ha^{-1}yr^{-1}$)

(g) Groundwater recharge: The increased area of bamboo forests reduces the runoff rate and assists water percolation. Bamboo has fibrous root system that grows up to a depth of 2 to 2 ½ cm from the ground surface. In a matured bamboo plantation of 4 - 5 years old, the root covers almost entire soil section to an extent of 30 - 40 % of the soil, the roots create anywhere between 200 to 400 mm of water. The excess water either goes as run off or charges the ground below where by increases the natural water table over a period of time.

Indicators of ES (Unit of measurement): • Water volume availability downstream (Megalitres $ha^{-1}yr^{-1}$).

(h) Water purification: Bamboo forests induce landscapes to filter out and decompose organic waste introduced into land and water and can assimilate and detoxify compounds through soil and subsoil processes.

Bamboo is the best Scavenger crop and suitable for Bio Remediation.

Disposal of municipal wastewater into rivers could affect water quality of river, marine biodiversity and threaten the existence of coral reefs. However, the same wastewater can be used as a 'resource' to enhance plant production, particularly for the biomass production for power generation.

Bamboo grows very well with waste as well as sewage water, it can resist many environmental stresses, including too little or too much water and withstands the range of temperature anywhere between 2ºC to 48ºC. The fibrous root system of bamboo is shallow and is capable of holding the water to an extent of 200 to 400 mm and bamboo is able to assimilate macro and micro nutrient and also absorb heavy metals from sewage water.

Indicators of ES (Unit of measurement): • Amount of quality/ pure water throughout the year (Megalitres ha/yr)

(i) Moderation of extreme events: Bamboo forests act as a natural buffer, helping to protect against wildlife attacks, strong winds, storms, landslides and other disasters and hence reducing damaging impacts. Vehicles moving on the highways derives energy from fuel by burning that converts one litre of fuel into 2.2 kg. of CO_2 on an average. The CO_2 emitted can be absorbed by planting rows of bamboo on either side of the road. Bamboo as carbon sink on plantation on either side of the road will keep on sequestering the CO_2 emission from the road, making it a "CARBON NEUTRAL ROAD". Growing trees on both sides of the roads are a common practice but most of the trees planted are slow growing and hence slow carbon absorption. Bamboo being the fastest growing plant, it is able to clean up the CO_2 faster. By planting required number of fast growing bamboo

plants, we can make a road carbon neutral, which means the emission of CO_2 by vehicle is proportionate to the amount of CO_2 absorbed by the tree on both sides of the road. The carbon neutral road will be one of the first step to make the country free from global warming. When one travels on a carbon neutral road, the fresh air picked up from the road during travel time shall have good level of oxygen as compared to regular roads with high level of CO_2. Other than making the road carbon neutral, planting bamboo on both sides would provide excellent tunnelling effect and reduces the noise pollution, especially in roads passing through reserve forest with wild life.

Indicators of ES (Unit of measurement): • Number of extreme events protected against (No. yr^{-1})

(iii) **Habitat services** that bring benefits to wildlife habitat and genetic diversity

(a) Habitat provision: Bamboo forests provide suitable habitat for different species of flora & fauna.

Indicators of ES (Unit of measurement): • No. of endangered species in the forest.

(b) Maintenance of biological diversity: Bamboo also plays an important role in maintaining wildlife biodiversity. Bamboo provides food and habitat for numerous species of insects in the soil mid tree layer, as well as for spider, butterflies, birds, and other higher life forms (Lou and Henley, 2010). Bamboo forests maintain and/or enhance biodiversity by promoting different varieties of bamboo species and providing habitat for wild animals.

Indicators of ES (Unit of measurement): • No. of species, ecosystems and genetic diversity

(iv) Cultural services including recreation, ecotourism, education and spiritual experiences. It contributes to wider needs and desires of society. Cultural services are deeply interconnected with each other and often connected to provisioning and regulating services. Cultural services are among the most important value people associate with nature so it is therefore critical to understand them.

(a) Landscape beauty: Bamboo forests create landscape beautification by preventing land degradation and enhancing landscape restoration and greenery. Bamboo is available in various colour, sizes, shape and height which give visual interest and a striking design to a landscape. Bamboos are valuable plants for using in a landscape design. In fact, they are excellent landscape plants for many reasons:

- Bamboos grow quickly and they are easy to maintain
- Bamboos come in hundreds of varieties that suit many purposes; they can be used as fencing plants, as wind breakers, as ground covers, as accent plants, and for controlling soil erosion
- Bamboos can grow in many different climatic conditions – tropical, cold, swamps, indoors, and in shaded and sunny locations
- Bamboos are resistant to pests and diseases
- Bamboos are evergreen and reproduce themselves easily

Clumping bamboos produce a different type of underground rhizome that sprout new stems (clums) next to the original plant, which then expand slowly each year. Clumping bamboo is most often used in landscaping because it's dense and fast - growing.

Common Clumping Varieties Used for Landscaping

- **Alphonse Karr or Multiplex Bamboo** - This species has golden culms (bamboo stems) striped with green. This variety can grow as high as 30 feet and is often used for privacy screens.
- **Golden Bamboo –** Golden bamboo is a commonly planted variety with finely textured green leaves and attractive golden - yellow stems. Usually used as a screening plant, it grows quickly more than 20 feet if not trimmed and spreads to create a dense hedge or screen. Unfortunately, this plant becomes invasive so it's not recommended for all gardens.
- **Giant Buddha's Belly** - This bamboo type features bulging "Buddha belly" culms and long, narrow green leaves, and can grow up to 50 feet.
- **Murray Island -** This type of bamboo forms dense clumps with lighter green, textured leaves and its lush top growth also makes it ideal for privacy screens. It grows up to 13 feet in height.
- **Chinese Dwarf Bamboo** – Compact and lush, this variety lends itself better to pot planting than other clumping species. Chinese Dwarf Bamboo is also a popular hedge choice and can grow up to nine feet tall.
- **Timor Black Bamboo** - This clumping form of black bamboo has light green leaves and dark culms with lighter stripes. It grows upwards of 50 feet.
- **Indicators of ES (Unit of measurement):** • Area of landscape covered by bamboo forest (area in ha) • No. of visitors appreciating the views of the landscape covered by bamboo forest.

(b) Recreation and ecotourism: Bamboo forests provide opportunities for ecotourism and recreational activities through the promotion of greenery and landscape beautification.

Benefits of Ecotourism: It has a minimal impact on the environment; Create awareness and respect for the local culture and the environment; Offers positive experiences for all;

Employs and benefits communities; Educate visitors about the local socio - political, and environmental issues.
Ecotourism with bamboo must be a model of harmony between agro - education, tourism and ecological preservation of the environment and of the culture. We can make our lives more valuable in a lifestyle and culture with bamboo.

Indicators of ES (Unit of measurement): • No. of recreation sites • No. of visitors per year

(c) Cultural/ religious values: Bamboo materials have been used from the cradle to the grave in many countries because of religious and cultural values associated with bamboo

Indicators of ES (Unit of measurement): • No. of cultural and religious events associated with bamboo

Bamboo forests Ecosystem Services compared with Other Ecosystem Services

At a particular point of time, both natural and planted forests supply a higher amount of raw/ construction materials as a provisioning service than do bamboo forests. In contrast, bamboo forests supply comparatively more biomass because bamboo has a shorter rotation (3–6 years) and a higher tree density (sometimes more than 10, 000 culms per ha) than other tree species. Thus, that they can provide many times the biomass and raw materials of tree species grown either in natural or planted forests, even within a single rotation period. One study shows that a plantation of giant bamboo (Dendrocalamus giganteus) with 200 bamboo clumps per hectare can give an annual yield of about 2000 poles with a biomass of as much as 50 tonnes (Ramanayake 2017). Similarly, it seems to have a higher production capacity of certain provisioning services such as food provision, forage production, timber and other construction materials, bioenergy and medicinal resources than that of natural forests.

When it comes to regulating services such as landscape restoration through the processes of sediment retention, floods and landslide control, moderation of extreme events, carbon sequestration and carbon stock of the bamboo forests were found to be higher than those of natural and planted forests (Yiping et al.2010; Yen and Lee 2011; Thokchom and Yadava 2015b; Yuen et al.2017; FAO and INBAR 2018). Similarly, bamboo forests have a higher capacity for groundwater recharge and a better local capacity to purify water than do natural forests. This is because a dense canopy with mixed and diverse vegetation types, particularly of natural forest, consume a higher amount of water than do forests with intermediate canopy cover (Ilstedt et al.2016). However, the rate of ES supply depends on the type of bamboo forest, where natural bamboo forests have a higher capacity than do planted monoculture bamboo forests (Yiping et al.2010). It is interesting to note that, except for natural forests, almost all of these regulating services were found to be higher in bamboo forests than in degraded forests, planted forests, grasslands and agricultural lands. As regards habitat provision, bamboo forests showed a higher capacity than planted forests and agricultural land, but lower capacity when compared with natural forests. Similarly, regarding cultural services, especially landscape beauty and ecotourism, bamboo forests had higher ES than degraded natural forests, grasslands and agriculture. The connection between ecology and management of bamboo, ecosystem benefits and approaches and tools for assessing ES from bamboo forests need to be illustrated because ES are strongly influenced by the silviculture and management methods.

The ES assessment of bamboo forests can serve many purposes, including: (i) raising clarity and awareness of the relative importance of bamboo forests to policymakers, investors, environmental NGOs and local communities, (ii) improving the efficient use of limited funds by identifying where bamboo forests can achieve enormous benefits at the lowest cost, (iii) supporting new opportunities to link bamboo forests with ES markets (Gu et al.2019), (iv) providing guidance for decision - makers in understanding user preferences and the relative value that people place on ES, (v) generating information for designing bamboo forests so as to maximize their contribution to local communities, broader society and the global environment, and (vi) showing the potentiality of bamboo plantation in the restoration of degraded land to achieve the aim of the UN Decade of Restoration (UNEP 2019). In the approach outlined here, the values ascribed to various ES are determined by the beneficiaries of the particular ES, which range from local to global markets.

Bamboo forests have great potential to store atmospheric carbon and their contribution to global climate change, there urgent need for management that promote extensive bamboo production for alternative wood source and bamboo carbon farming.

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