Ecosystem services from coconut based cropping system

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Introduction

The term "ecosystem services" is often used interchangeably with the terms, "environmental services" and "ecological services." Ecosystem services are "goods and services" derived from "natural processes and components of an ecosystem," that are directly or ultimately beneficial to humans. Ecosystem services have been divided into four broad categories *viz.* ***provisioning services*** (for example food, water, biochemicals, industrial products and energy), ***regulation services*** (such as water and soil regulation, carbon sequestration and climate regulation, waste decomposition and detoxification, crop pollination, pest and disease control), ***supporting services*** (include nutrient cycling, soil formation, seed dispersal and primary production) and ***cultural services*** (education, recreation, aesthetic, and spiritual values).

One of the most important outcomes of the global Conference of Parties (COP-II) of the Convention of the Biodiversity held during October this year at Hyderabad was finding of The Economics of Ecosystems and Biodiversity studies. The findings revealed that nature is critically important to the livelihood of millions, and in India, 47 per cent of the 'GDP of the Poor' comes from ecosystem services.

It therefore has become extremely vital that we must become aware of ecosystem services, determine the economic values of ecosystem goods and services for each of the key ecosystems in the priority zones for the entire country and link with economic valuation of environmental impacts and benefits of the services. Evaluation alone is not enough; everyone should be paying for their impacts on, use of, and reliance on ecosystem and its services, if they want it to continue to be available. Unless such economic value is fixed and charged for its use, the ecosystem services will be ignored and continue to degrade putting enormous burden on survival of the human beings, plants, animals and other living organisms on the Earth.

Ecosystem services through plantation crops

Plantation crops such as coconut, arecanut, cocoa, coffee, tea, oil, palm and rubber have been recognized for provision of a wide range of ecological benefits besides the productive function. Plantation cropping systems in 3 which crops (like coconut + banana + black pepper or coffee + cocoa + bananas etc) are recognized for production, regulatory, cultural and supportive services like provision of food, carbon sequestration, facilitating aquifer recharge, providing recreational landscapes, plant and animal biodiversity conservation that enhances systems' ability to supply ecosystem services, prevention and control of soil erosion, pest control, enhanced pollination and fruit set, nitrogen fixation and nutrient recycling, reduction of heat-induced stress etc.

Ecosystem services offered by coconut

Coconut, for example, is called 'Kalpavriksha' the tree which gives all that is necessary for living is an epitome of ecosystem services offered by any plantation crop. It is a traditional crop grown in India with a long history of cultivation of more than 3000 years. The area under coconut cultivation in India is around 1.9 million hectares with the production of 15730 million nuts and per hectare productivity of 8303 nuts. As an oil seed, coconut holds 15.2 per cent share of the entire oilseed value output in the country. In India, most of the production comes from small and marginal farms and more than 90% of the holdings are below one hectare with the average size being 0.22 ha. The export earnings derived by India from coconut are around 13370 million rupees, mainly through the export of coir and coir products. The processing and related activities centred on the crop generate employment opportunities for over two million people in India. In addition, the crop contributes 83000 million rupees annually to the Gross Domestic Product (GDP) of the country.

The palm is essentially a tropical plant, growing mostly between 20° N and 20° S latitudes in loamy, laterite, and coastal sandy, alluvial and reclaimed soils. The ideal temperature for coconut growth and yield is $27 \pm 5^{\circ}C$ and humidity > 60 per cent. The coconut palm grows well up-to an elevation of 600 m above MSL. However, near the equator, productive coconut plantations can be established up to an elevation of about 1000 m above MSL. A well distributed precipitation of about 200 cm per year is the best for proper growth and higher yield. In areas of inadequate rainfall with uneven distribution, irrigation is required.

The crop provides livelihood security for several millions of people who depend on it one way or the other and supplies raw materials to host of industries. Every part of coconut is used for one or the other purposes *viz*. food and beverage, medicine, cosmetics, industrial raw material, construction material, cultural and religious functions etc. However, these points consider only a part of the benefits that coconut palm offers to the humans, particularly food and monetary. The wider and more relevant fact of coconut cultivation is not only the socio-economic assistance but also the conservation aspects, *i.e*. the ecosystem services it provides.

The Central Plantation Crops Research Institute (CPCRI), earlier known as The Coconut Research Station was established by Government of Madras in 1916. Later it was taken over by The Indian Central Coconut Committee in 1948 followed by Indian Council of Agricultural Research (ICAR) in 1970. The CPCRI is mandated to work on coconut, arecanut and cocoa. The Institute Headquarter is located in Kasaragod, Kerala. Its three Regional Stations are at Kayamkulam (Kerala), Vittal (Karnataka) and Minicoy (Lakshadweep Islands) and three Research Centres at Kahikuchi (Assam), Mohitnagar (West Bengal) and Kidu (Karnataka) catering to the research needs of the mandate crops at the National level. The All India Coordinated Research Project on Palms (AICRP-Palms) with 13 centres located in seven State Agricultural Universities and one Central Institute, initiated in 1972, is the partner in taking forth the research and development technologies of to wider parts of the country where coconut is grown.

The contribution made by CPCRI in the research and development of coconut palm is significant. The Institute has 401 coconut accessions (269 indigenous and 132 exotic) which is the largest collection in the world showcasing the diversity of coconut. This diversity holds invaluable genetic material that can help in development of coconut crosses/hybrids with traits to overcome many of the biotic and abiotic stress. The Institute has released nine improved coconut varieties and five hybrids. Several technologies to enhance yield of the nuts, control insect pest and diseases, and produce post-harvest products have been developed by CPCRI that has been helping the farmers' dependent upon coconut for their livelihood.

The coconut based cropping systems typically enrich the biodiversity of the area with different crop combinations, animal, fishery and poultry and provide several important ecosystem services under the main four categories.

Provisioning services

The endosperm of coconut and coconut water by itself is an important source of food for many dependent upon this plantation crop. The coconut flower sap obtained on tapping the inflorescence is rich in sugar and is converted into jaggery, sugar, vinegar and sweet or fermented toddy. The coconut oil cake, a by-product in coconut-oil processing, is a valuable cattle feed. The interspaces in coconut farm allow cultivation of many perennial and annual crops that also provide a variety of food and food-products.

Among the production technologies developed by CPCRI, the concept of coconut based-cropping systems that taps the basic resources such as space, light and nutrient for enhancing the income of the farmers is most noteworthy contribution of this Institute. The coconut based High Density Multiple Species Cropping System (HDMSCS) that allows cultivation of intercrops such as banana, black pepper, pineapple, tapioca, elephant foot yam, and nutmeg has been a standout technology. The coconut based mixed farming system integrates dairy, fodder grass cultivation, fishery, poultry and biogas production providing a self-sustaining energy and nutrient utilization loop with high net returns. The yield from banana, black pepper, pineapple, nutmeg, tapioca and other inter crops grown in coconut based HDMSCS provides food material round the year as well as steady income to the farmers. Protein rich food is obtained such as milk, egg, poultry, duck and goat meat through animal farming. The excreta of the animals help in rejuvenating the fertility of the soils. The cow-dung and cattle shed washes are used in bio-gas production for meeting the energy need of the family adopting coconut based mixed farming system.

The coconut oil forms an important component of pharmaceutical, biochemical and industrial products highlighting the provisioning services of coconut cultivation. In recent times production of virgin coconut oil (VCO) has become the newest high-value product in market from coconut producing states. CPCRI has developed three processes for production of VCO viz. i) hot processing method, ii) natural fermentation process and iii) centrifugation process that caters to different degree of scale of adoption depending upon investment strength and market demand.

The coconut palm generates lots of biomass which can be used for many useful purposes. It is reported that one hectare coconut farm with bearing palms generate around 8-11 tonnes of biomass waste which can serve as source of kitchen fuel, roofing and fencing material of many homes having coconut palms.

CPCRI has developed a useful recycling technology for on-farm production of compost and vermicompost from coconut biomass wastes. The vermicompost production technology from coconut leaves using a local strain of African night crawler earthworm, *Eudrilus* sp. has been one of the most significant farmer friendly technologies developed by CPCRI. The coconut leaf degrading *Eudrilus* sp. is able to convert pineapple wastes, banana pseudo-stem lopping, and coir-pith also to vermicompost when mixed in 1:3 ratio with coconut leaves. In this way biomass waste generated from coconut based HDMSCS is more effectively used for nutrient management of the crops. Coir-pith composting technology without the use of urea and with use of poultry manure along with rock phosphate and lime too has been developed at CPCRI for effective utilization of coconut waste biomass.

Another useful approach for recycling of coconut wastes is by utilization of the lignocellulosic biomass for oyster mushroom cultivation and further conversion of the spent substrate to organic manure by composting or vermicomposting. Coconut leaf stalk, bunch waste or a combination of leaflets + bunch wastes were better substrates for oyster mushroom cultivation, which gave a biological efficiency (BE) of conversion of 55-70%. The *Pleurotus* species found suitable for mushroom production on coconut wastes were *P. florida, P. sajor caju, P.flabellatus* and *P.eous*.

Coconut shell and husk, coir-pith are a good sources of biofuels. The Coconut Methyl Ester (CME), or the Coconut Biodiesel produced from coconut oil is a renewable source of energy. CME provides excellent lubricity, solvency and detergency. Studies show that the addition of CME results in better combustion, less pollution, and more engine power and could be one of the major source of energy and power production in regions where coconut is grown. For example, it has been reported that coconut biodiesel can yield reductions of 81 to 109% in net CO_2 emissions relative to petroleum diesel. An autorickshaw driver Mr. G. Rajeevan from Kasaragod has reported that coconut oil could be used as an effective alternative to conventional lubricant for small automobile engines. The Kerala State Council for Science, Technology and Environment (KSCSTE) has shown support to the innovator and has asked Kerala Agricultural University to take up more studies on this report.
The Central Coir Research Institute at Alleppey has developed technology for production of coir geotextile which is being widely used in many hilly areas to prevent soil erosion and anchoring the loose top soils. It has also developed coir-pith composting technology using microbial consortia. Charcoal produced from coconut shell is one the best nano material for filtering waster and other toxins.

Regulating services

Some of the components under regulating services are carbon sequestration and climate regulation, waste decomposition and detoxification, purification of water and air, crop pollination, pest and disease control.

Coconut palm trunk acts as a substantial sink for atmospheric carbon helping in carbon sequestration. CPCRI has carried out studies to determine the whole plant (above ground) carbon stocks and sequestrations in coconut plantations under different agro-climatic zones. The results indicate that annual C sequestration in coconut above ground biomass varied from 15 to 35 t CO_2/ha/year depending on cultivar, agro-climatic zone, soil type and management. Annually sequestered carbon stocked in to stem in the range of 0. 3 to 2. 3 t CO_2/ha/year. Annual carbon sequestration by coconut plantation is higher in red sandy loam soils and lowest in littoral sandy soils.

It is also reported that coconut palms help in prevention of soil runoff and soil erosion, particularly the tall varieties giving more protection than the dwarf coconut palms. The canopy of the bearing adult palms as well as its undergrowth provides ground cover thereby intercepting raindrops and reducing terminal velocity of raindrops, which otherwise would detach the soil particles on the top soil and cause severe soil erosion. Such protection leads to soil and water conservation which is higher when there are other short season and long-term crops grown in the coconut inter-spaces.

Coconut gardens host different types of insects like the ants, bees, wasps, and earwigs etc that visit or inhabit the coconut palm. Most of these insects are known pollinators. In addition to hosting beneficial insects, coconut palm are attacked by coleopterans, lepidopteron and acarine insect pests that cause severe yield loss, damage or death to the palm. Many different kinds of plant pathogenic fungi also are found in the coconut ecosystem causing important economic damage to the palm. These are the fauna that are normally associated with the coconut and they must be playing an overall important role, even if it is damaging or beneficial, in the ecosystem services provided by this plantation crop.

The various coconut based cropping systems has its own effect on the weather parameters and thus could be regulating the climate of that area. Perhaps, because of the dense green canopy put up by the coconut gardens in West Coast of India the microclimate above it must be enhancing the precipitation of the monsoon clouds. Not to mention that such precipitations bring down much needed nutrients like nitrogen, phosphorus and sodium which could be of help to the largely rain-fed grown coconut in Kerala. A crop population with a diverse genetic makeup may have a lower risk of being entirely lost to any particular stress, such as temperature extremes, droughts, floods, pests, and other environmental variables. Crops with different planting times and times to maturity give the farmer the option to plant and harvest crops at multiple points in the season to guard against total crop loss to environmental threats.

Cultivation of coconut along the coastal belts has known to save the hinterland from cyclonic storms and tsunamis by absorbing the destructive forces of the wind and water acting and acting as a bio-shield. The islands of Lakshadweep and Andaman and Nicobar have coconut palms as one of the main sources of food, fodder, fibre and shelter material. The Island ecosystem is entirely dependent upon the ecosystem services provided by the palms. To much extent the palms lining the coasts of these islands act as the first defence mechanisms against the destructive cyclonic and tsunami forces.

Supporting services

The coconut palm is a perennial crop. It starts yielding from 5 or 6th year onwards and continues actively up to 40 to 50 years. During the course of its living it constantly mines the soil for nutrients and conversely each year it sheds 8-11 tonnes of biomass wastes. The biomass waste volume increases many fold in coconut based cropping HDMCS and mixed farming systems. The results from studies conducted at CPCRI, Kasarasgod revealed that the annual biomass removed from the system ranged from 17.7 to 24.8 t/ha/year out of which the quantity of biomass available for recycling under coconut-based HDMSCS at Kasaragod ranged from 12.7 to 18.5 tonnes/ ha/year in the form of leaves, inflorescence waste and husks under different fertilizer level. This large amount of biomass wastes become a significant source of plant nutrients when recycled through composting/ vermicomposting technology developed at CPCRI. The vermicompost / compost is able to return valuable organic carbon, major, minor and micro nutrients, plant beneficial microorganisms to the soil that reduces the application of synthetic fertilizers to 1/3rd proportions for getting high nut yield. Studies carried out by CPCRI have shown that there is an enrichment of plant beneficial microbial communities during the conversion of coconut leaf substrate to vermicompost. Addition of this vermicompost significantly increases the microbial biomass, diversity and fertility of the soils.

Soil microorganisms form one of the major below ground biotic factors involved in recycling of the nutrients effectively in any system. Extensive studies conducted at CPCRI has revealed that coconut rhizosphere harbours a wide range of beneficial microorganisms such as nitrogen fixing diazotrophs, phosphate solubilizing bacteria, plant growth promoting bacteria and arbuscular mycorrhizae which take part in improving the nutrient and fertility status of soils. The belowground microbial diversity increases from the mono-cropped coconut garden to multiple cropped coconut gardens and is greatly influenced by the above ground vegetation type. In coconut based HDMSCS and mixed farming systems the increase in microbial diversity, microbial biomass and earthworm populations was observed. The functioning of the below ground microbial communities thus greatly influences the stand of the above ground vegetation and both are highly interrelated. This forms an important supporting ecosystem service provided by the coconut based cropping systems.

Cultural services

Cultivation of coconut palm has deep rooted cultural and spiritual connections in India. Growing coconut palm is equated with bringing up a child, to this extent it is involved in the locals' existence. The palm plays an important role in the life of the farmer. Not only it provides materials for living,

the de-husked coconut forms an important offering to the deities in Hindu temples and during the many family and social festivities. Some of the coconut palms, particularly those growing in Lakshadweep islands, produce small sized coconuts that are very popular in temples of remote areas in Northern India. This is because the small sized nuts are easy to transport to these locales and serve the purpose of religious needs. During temple festivals in Kerala where local folk dances are performed many parts of the coconut palm are used for dressing the performers. The coconut inflorescence and the leaves are used as decorative buntings for all social and cultural celebrations in many parts of Southern India. Artists, be it painters, poets, song writers, photographers or film producers never miss to highlight the role of coconut palm in the lives of those dependent upon the crop. Not more can be mentioned about the importance of coconut palm than the State Kerala getting its name from this important plantation crop.

The western Coast of India, from Goa down to Thiruvananthapuram and some parts of eastern Coast lined with the swaying coconut palms making the stretches of the nation into most attractive tourist destinations. The tourism industry benefiting enormously by the palms fringed locales helps generating a substantial amount of income to the local Government and the population that caters to tourism based enterprises. An eloquent commentary on the coconut palm transforming the islands of Golden Barrier Reef in Australia into earthly paradise is also reported. However, it has become imperative that such tourism must be a responsible one taking care of the environment and respecting the local customs and the community.

Conclusion

It is much evident that coconut based cropping system offers all the four categories of ecosystem services. Similar services are offered by other plantation crops such as arecanut, cocoa, oil palm coffee, tea and rubber. A more properly researched work in this aspect could add to the public opinion and decision makers of its importance and make us realize the need to improve the production and productivity of this crop for sustaining its ecosystem services.