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Payment for Ecosystem Services in Agriculture

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Preface

Declining landholding size, quantitative and qualitative deterioration of land and water resources, increasing frequency of extreme climatic events and rising input costs accompanied by high volatility in output prices have been affecting economic viability of agriculture, leading to a situation of agrarian distress in many parts of the country. On the other hand, agriculture remains under a continuous pressure to produce more food, feed, fodder and fibre to meet the demand of the growing population, and without causing damage to natural resources, environment and human health.

The policies and incentives that boosted agricultural productivity and food supplies in the initial phase of Green Revolution seem to have lost their steam, and become less relevant in the changing global economic environment. It calls for a re-look into the existing agricultural incentive structure, and concomitantly search for alternative ways that can help improve efficiency and sustainability of agricultural ecosystem. Towards this, a plausible yet less explored option is to provide economic incentives to farmers for ecosystem services that they provide to the society at zero marginal cost through management of their land, water and other resources. To explore this, the National Academy of Agricultural Sciences organized a brainstorming session on October 31, 2019.

This policy paper is an outcome of the discussion on some important aspects of agri-ecosystem services in this brainstorming session. It presents an in-depth analysis of agri-ecosystem services and a framework for their valuation, and subsequently it provides insights into the feasibility of a change in the incentive structure in favour of a system of 'Payment for Ecosystem Services (PES)'. I, on behalf of the Academy, thank Drs P.S. Birthal and Saudamini Das for synthesising the opinions, comments and suggestions of the participants in the form of this document. I am grateful to all of the participants. My sincere thanks are due to Drs Kusumakar Sharma and P.S. Birthal for their editorial support in bringing this document in its present shape.

(Trilochan Mohapatra)
President

Payment for Ecosystem Services in Agriculture

1. INTRODUCTION

Globally, agriculture is the largest, most dynamic and economically important ecosystem, because of its critical importance to the food and nutritional security of nations and livelihoods of millions of people, including the farmers, farm workers, traders, processors and exporters, engagedat different segments of the agri-food value chains. The importance of agriculture, however, transcends beyond its direct food and non-food provisioning functions.Simultaneously, it generates a range of visible and invisible, direct and indirect services, 'known as ecosystem services', that benefit the society in several ways. The environmental and socio-cultural benefits of ecosystem servicesal though are widely recognized in the extant literature, but these have not been evaluated from an economic perspective.

In the past half century, technological changes in agriculture and allied sectors, supported by investments, infrastructures, institutions and incentives, propelled several developing countries, including India, towards self-sufficiency in food as well as in several non-food agricultural commodities. Nonetheless, some of the economic incentives that boosted agricultural productivity and food supplies have now become less relevant, causing damage to natural resources (i.e., land and water) and environment. For instance, subsidies on fertilizers and electric power coupled with an assured procurement of paddy,a water-guzzling crop, at government-set pre-announced minimum support price have caused severe degradation to natural resources, i.e., land and water, beyond their sustainable limits in some states of India (for example, Punjab and Haryana). Additionally, climate change has emerged a big threat to sustainable development of agriculture and agriculture-based livelihoods. Extreme climatic events, such as droughts, floods and heat-waves, have become frequent, and these are predicted to become even more frequent in the plausible future climate scenarios. Further more, India's land frontiers have been closing down – the net cropped area has remained almost stagnant in the past five decades, indicating limited prospects of its further exploitation for agriculture. On the other side, the need to produce more food, feed, fodder, fuel and fibre to meet the demands of growing population remains as urgent today as in the past. By 2050, India's population is expected to increase to 1.64 billion, requiring almost double the food than at present.

These concerns call for a re-look into existing agricultural incentives and a search for their alternatives that can help improve efficiency and sustainability of agricultural production systems. A plausible, although less explored, option is to pay farmers for ecosystem services (e.g. carbon sequestration, hydrological balance and climate regulation) they provide to society through agriculture. In recent years, there has been an increasing realization of the role of ecosystem services in conservation of natural assets that are critical to the sustainability of agricultural production system and social welfare (Cullen et al., 2004). And, probably it is this recognition that has compelled scientific community, developmental organizations and policymakers to re-look into the relationship between man and nature, and search for alternative technological, institutional and policy options for a synergistic healthy relationship among ecosystem, economy and society. Towards this, Costanza (2006) suggests evolving an incentive structure linked with ecosystem services.

Ecosystem services from agriculture have not received much attention, and have remained unquantified or undervalued from an economic perspective[1]. This is because of the missing markets for such services and/or market failure (Power, 2010; Baskaran et al., 2009). This has resulted in an incomplete understanding of economic contributions of ecosystem services that agriculture generates, and channels through which these can be mainstreamed into agricultural policy and development agenda (Balmford,et al., 2002).

This paper provides an overview of agri-ecosystem services, their methods of valuation, and prospects of their mainstreaming into agricultural policy. The following section presents concept of ecosystem services and a theoretical framework for their valuation. Section 3 provides an overview of methods of valuation of ecosystem services. The need for mainstreaming of ecosystem services in agricultural and rural development agenda is discussed in Section 4, and key recommendations are given in the last section.

2. CONCEPT AND THEORETICAL FRAMEWORK

2.1 Concept of ecosystem services

Ecosystems are defined as the conditions and processes through which natural ecosystems and species fulfil and sustain societal needs; and ecosystem services (ES) are the benefits that an ecosystem provides to the society through ecosystem functions (MEA, 2005), *that is the capacity of natural processes and components to provide goods and services to satisfy human needs directly or indirectly* (De groot *et al.,* 2002). Ecosystem goods (i.e., food, feed, fodder, fuel and fibre) and services (i.e., biodiversity, climate regulation, recreational activities, water availability, water quality and soil functionality) represent benefits that society derives directly or indirectly from ecosystem functions (Costanza et al., 1997a; Daily, 1997).

[1]http://www.fao.org/3/i1688e/i1688e03.pdf

The concept of ecosystem services started gaining importance in the 1960s (King, 1966; Helliwell, 1969; Odum and Odum, 1972), and since then these have been studied from several angles including their environmental, social, cultural, recreational and economic functions. De groot et al. (2002) provide a systematic typology of ecosystem functions, and a comprehensive framework for their evaluation from an economic perspective. They classify ecosystem functions into four broad categories:

(i) **Functional** grouping that includes regulation, carrier, habitat, production and information services (Lobo, 2001; de Groot et al., 2002).

(ii) **Organizational** grouping includes the services associated with certain species that regulate some exogenous inputs or that are related to organization of biotic entities (Norberg, 1999).

(iii) **Descriptive grouping** includes renewable and non-renewable resource goods, and physical, biotic, geo-chemical, social and cultural services (Moberg and Folke, 1999).

(iv) **Economic preference** based grouping includes the actual use (direct as well as indirect), optional use and non-use (existence and bequest) values (Krutila, 1967).

The seminal contribution of Costanza et al. (1997b) towards understanding the relationship between ecosystem services and social welfare led to an increased recognition of the economic contributions of ecosystem services in planning and implementation of the environmental and developmental programs. Subsequently, a comprehensive theoretical framework for their assessment termed as' The Millennium Ecosystems Assessment' was proposed by the United Nations (MEA, 2005). MEA(2005) has used functional grouping to categorize ecosystem services as supporting, provisioning, regulating and cultural services;and established their links with components of social welfare (Figure 1).

Supporting services (e.g., soil formation and nutrient cycling) are basic to utilizing the other three services, i.e.,provisioning, regulating and cultural. Most of these services have no market substitutes, and once lost the society suffers an irreversible loss. Any damage to natural resources resulting in loss of supporting services is an irreversible loss[2].

Provisioning, regulating and cultural services contribute directly to social welfare, the constituents of which are classified as environmental security and availability of basic materials for a good life, health and social relations. Any society in which these components are available is considered well-off and has the freedom of choice and action, i.e.,opportunities to pursue one's cherished goals. If an ecosystem gets degraded the social welfare is automatically adversely affected.

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[2]Earthworms provide nutrient cycling of the soil that promote productivity. Human activity that kills earthworms causes an irreversible loss.

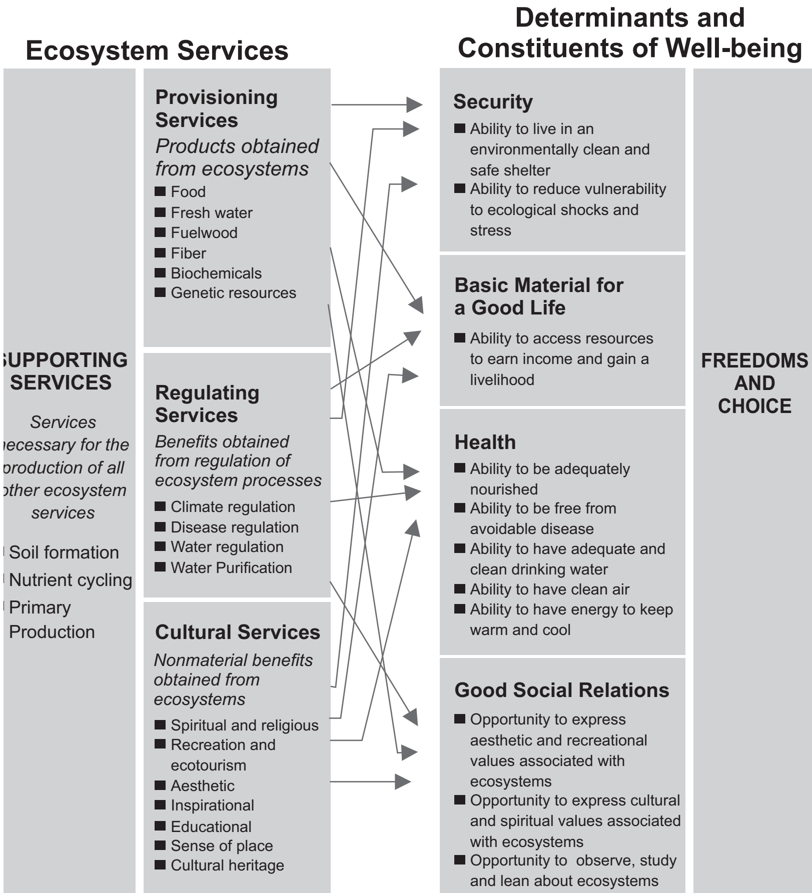

Figure 1. Functional categorization of ecosystem services
(Source: MEA, 2005)

Agriculture, unlike other natural ecosystems, is a man-made, managed, and regulated ecosystem that primarily produces food for human beings and raw material for industrial uses. Nonetheless, it also produces several ecosystem services, both positive and negative, as an adjunct of the food production function. Following MEA (2005), ecosystem services from agriculture can be assigned to any of the following functional categories:

(i) **Provisioning services:** food, fodder, raw materials, medicines, etc.

(ii) **Supporting services:** nutrient cycling, soil retention, enhancing soil fertility, genetic diversity, supporting biodiversity, etc.

(iii) **Regulating services:** water recharge, water cycling, pollination, biological pest control, carbon sequestration, climate regulation, etc.

(iv) **Cultural services:** recreation, religious and cultural values, research and development, etc.

Since agriculture is a man-managed ecosystem the flow of services from it depends on management practices being followed at farm-level. It can also generate ecosystem dis-services or negative externalities, such as loss of biodiversity, chemicalization of soils, water and air, soil sedimentation, pesticide poisoning and greenhouse gas emission, all affecting the efficiency and sustainability of agricultural system, and consequently the social welfare.

2.2 Theoretical framework for valuation of ecosystem services

The 'Economics of Ecosystem and Biodiversity (TEEB)' is another important global initiative of the United Nations that intends to make value of the nature visible. It attempts to demonstrate, assess and mainstream values of biodiversity and ecosystem services in land-use and policy decisions. It uses preference-based grouping of ecosystem services, i.e., use and non-use values, for monetisation of these services (TEEB, 2012). Table 1 shows preference-based categorization of ecosystem services.

Table 1. Typology of values based on human preferences

Value type	Value by sub-type	Description
Use values	Direct use values	Results from the direct uses of biodiversity by humans (*consumptive or non-consumptive uses*).
	Indirect use values	Derived from the regulatory services provided by the species and ecosystems
	Option values	Relates to the importance that people put to the future availability of ecosystem services for personal benefits (*option value in a strict sense*).
Non-use values	Bequest value	Value attached by individuals to the fact that future generations will also have access to the benefits (*intergenerational equity concerns*).
	Altruist value	Value attached by individuals to the fact that other people of the present generation have access to the benefits provided by species and ecosystems (*intra-generational equity concerns*).
	Existence value	Value related to the satisfaction that individuals derive from the mere knowledge that species and ecosystems continue to exist.

Source: TEEB (2012)

Society derives two types of values from nature: use values, and non-use values. Non-use value means that nature is valuable to mankind even if it is not used. Use values include direct uses (e.g., food, fibre, tourism, research and cultural), indirect uses (e.g.,

[3]These values are anthropogenic as these are derived from human uses and people's preferences are studied to assign values to ecosystem services

flood control, carbon sequestration and storm protection) and an option of using these in the plausible future. Non-use values could arise due to different motives– the bequest (*use by future generations*), the altruist (*use by other members of society*) and the existence (*ecosystems should exist even if nobody will use it*).

Economists have assessed valued some direct and indirect uses of ecosystem services. Valuation of non-use and optional use, however, has received little attention primarily because of the inherent difficulties in capturing bio-physical parameters of ecosystem services amenable to an economic valuation.

TEEB uses a total economic value (TEV) framework to monetise ecosystem services (Table 2). Provisioning services include direct and option use values, as these are used directly by human beings or can be used at a future date. Similarly, regulating services have indirect uses, as these cannot be used directly by the society. Cultural services have direct, option and non-use values but not indirect use values. As mentioned before, supporting services are basic to generating provisioning, regulating and cultural services, and to avoid their double counting these are excluded from the valuation framework.

Table 2. Valuing ecosystem services in the total economic value (TEV) framework

Group	Service	Direct Use	Indirect use	Option value	Non-use value
Provisioning	Includes: food; fibre and fuel; biochemicals; natural medicines, pharmaceuticals; fresh water supply	√	NA	√	NA
Regulating	Includes: air-quality regulation; climate regulation; water regulation; natural hazard regulation, carbon storage, nutrient recycling, micro-climatic functions etc.	NA	√	√	NA
Cultural	Includes: cultural heritage; recreation and tourism; aesthetic values	√	NA	√	√
Habitat (supporting) Includes: primary production; nutrient cycling; soil formation. Habitat services are valued through the other categories of ecosystem services					

NA - Not Applicable

Source: TEEB (2012)

3. METHODS OF VALUATION OF ECOSYSTEM SERVICES

Figure 2 summarizes the existing methods of valuation of ecosystem services. As mentioned before, ecosystem services are anthropogenic, derived from an analysis of the behaviour of individuals and/or their preferences. Thus, depending on the type of a

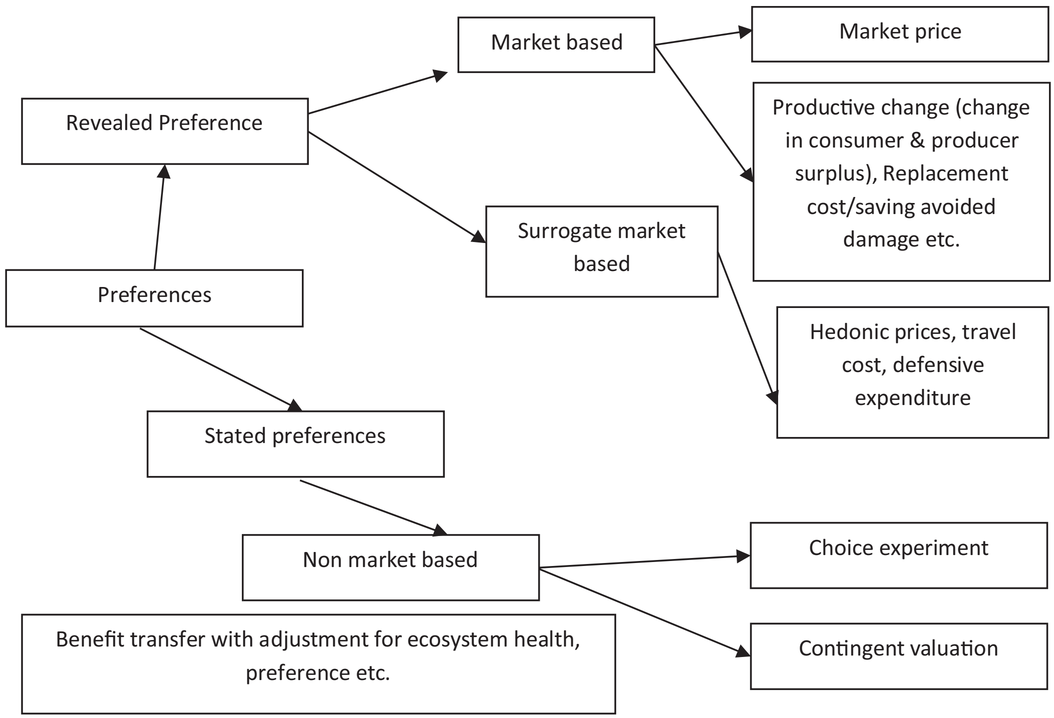

Figure 2. Economic methods used for valuation of ecosystem services
(Source: Authors' compilation)

service, one can use either a revealed preference or a stated preference method to assign economic value to a service.

Tradable provisioning services can be valued using market prices. Non-market or surrogate market-based valuation methods can be employed for valuing regulatory and cultural services that are invisible public goods and are not tradeable. Nevertheless, the process of valuation of non-marketable services is complex, and requires inputs from experts cutting across disciplinary boundaries of the agricultural science.

Valuing ecosystem services from agriculture is inherently difficult, as agriculture is an engineered landscape influenced by its surrounding socio-cultural, political and economic environments (Power, 2010). The economic values of agri-ecosystem services are, thus, relative and context specific. For example, while producing provisioning services, some management practices and interventions may cause negative externalities to the ecosystem itself and the surrounding ecosystems. Therefore, it is important that such trade-offs be captured in the assessment of total economic value of an agricultural ecosystem.

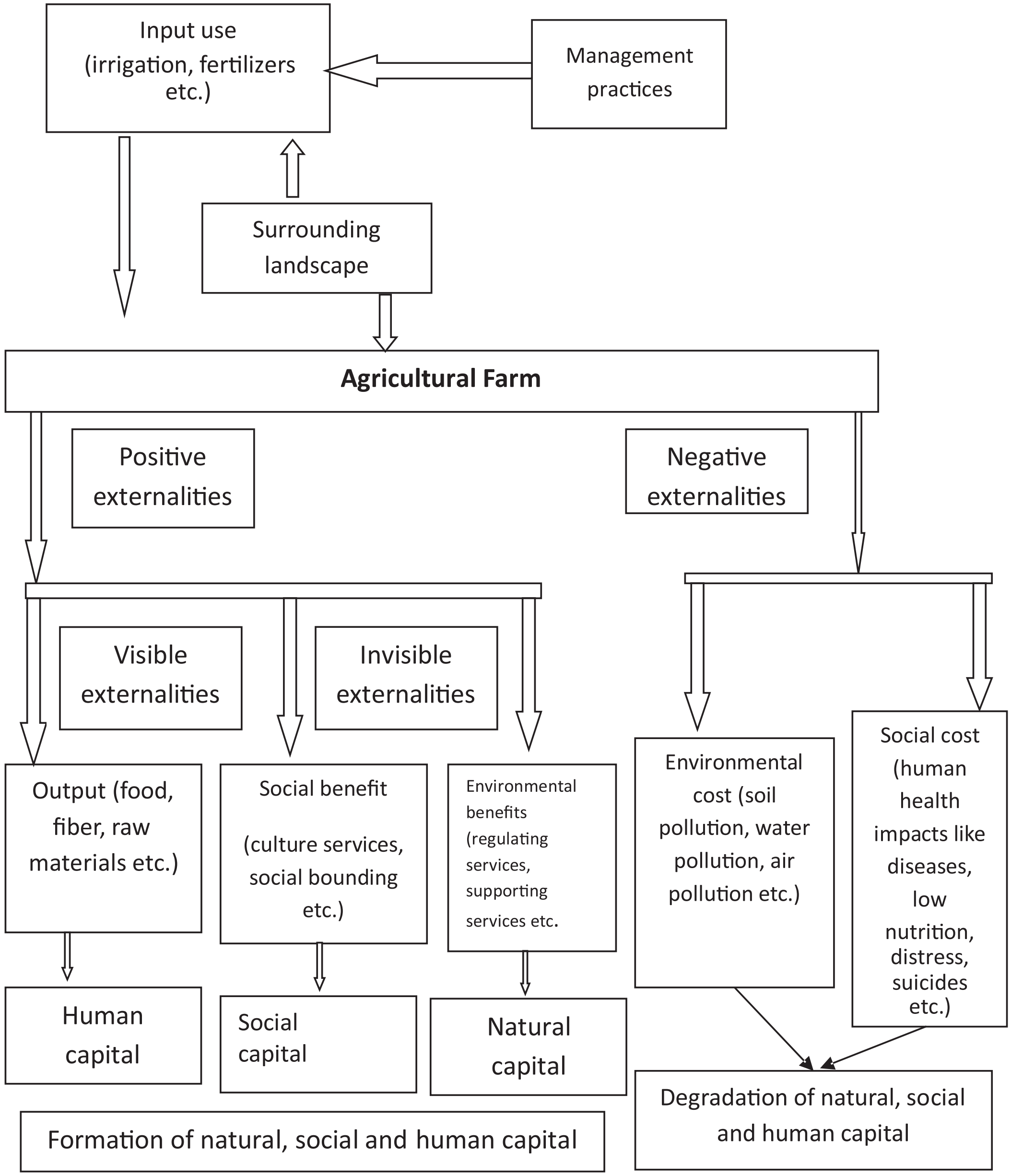

Figure 3: Conceptualization of the flow of externalities from agri-ecosystem
(Source: Authors' compilation based on Sandhu, 2018)

Following conceptual framework outlined in Figure 3 the TEV approach can be utilized to measure net flows of ecosystem services as:

$$TEV_i = Pb_i + Eb_i + Sb_i - Ec_i - Sc_i$$

where, *TEV* is the total flow of economic values on ith farm. *Pb* represents the production benefits (*food, fibre, raw material, etc. which are visible), Eb are the environmental benefits (pest control, water recharge, pollination and carbon sequestration that are invisible services*), *Sb* are the social benefits (*employment, cultural, religious, research, recreation etc.*), *Ec* are the environmental costs (*soil, air, water pollution*) and *Sc* are the social costs (*human health impacts*). A combination of market based (*revealed preference*) and non-market based (*stated preference*) valuation techniques can be used to monetise ecosystem services.

Globally, ecosystem services from agriculture have remained unquantified or undervalued because of the lack of bio-physical information on their intangible benefits and costs,and also because of their interdependence on adjoining landscapes (Power, 2010). An agri-ecosystem offers several non-market services such as climate regulation, managing surface water flow, maintaining groundwater resources, assimilation and breakdown of wastes and nutrient recycling (Swinton et al., 2006) that come as invisible by-products of food and non-food production functions of agriculture, and are available to the society at zero marginal cost (Dale and Polasky, 2007).

Nevertheless, efforts have been made to assign economic values to some ecosystem services from agriculture. Table 3 shows estimates of economic values of a few agri-ecosystem services (Ploeg and de Groot, 2010). It is observed that: (i) most of these estimates are derived employing the 'benefit transfer method', which is based on strong assumptions regarding the costs and benefits of ecosystem services, (ii) these estimates pertain mainly to the developed countries, and (iii) even estimates for an ecosystem service may vary widely across countries.

Some scientific studies from India provide biological and physical parameters for a few ecosystem services, that can be utilized for their monetisation; for example, biological nitrogen fixed by leguminous crops, and nitrogen supplied through incorporation of crop residues in the soils. Nonetheless, hardly any attempt has been made to assign an economic value to these parameters.

Table 3. Annual values of select ecosystem services as reported in TEEB Data Base

Service valued	Sub-service	Country	Year	Method used	Value estimate	Unit (s)
Air quality	Capturing fine dust	China	2004	Benefit transfer	484	CNY/ha/yr
Bio-control	Biological control	Spain	2004	Benefit transfer	30	USD/ha/yr
Climate	Climate regulation	China	2004	Benefit transfer	861.6	CNY/ha/yr
Erosion	Erosion prevention	USA	1992	Replacement cost	106.25	USD/ha/yr
Erosion	Erosion prevention	USA	1992	Mitigation, restoration cost	40	USD/ha/yr
Food	Plants / vegetable food	Tanzania	2000	Direct market pricing	62.8	USD/ha/yr
Food	Food [unspecified]	China	2004	Benefit transfer	968.1	CNY/ha/yr
Genepool	Biodiversity protection	Spain	2004	Benefit transfer	2053	USD/ha/yr
Genepool	Biodiversity protection	China	2004	Benefit transfer	687.3	CNY/ha/yr
Pollination	Pollination [unspecified]	Spain	2004	Benefit transfer	20	USD/ha/yr
Raw materials	Raw materials	China	2004	Benefit transfer	96.8	CNY/ha/yr
Recreation	Recreation	Spain	2004	Benefit transfer	37	USD/ha/yr
Recreation	Recreation	China	2004	Benefit transfer	9.7	CNY/ha/yr
Soil fertility	Maintain soil structure	China	2004	Benefit transfer	1413.4	CNY/ha/yr
Soil fertility	Maintain soil structure	USA	1992	Replacement cost	168.75	USD/ha/yr
TEV	TEV	Spain	2004	Benefit transfer	2140	USD/ha/yr
TEV	TEV	China	2004	TEV	6689.5	CNY/ha/yr
TEV	TEV	Australia	2005	TEV	165.43	AUD/ha/yr
TEV	TEV	USA	1997	Benefit transfer	92	USD/ha/yr
Waste	Water purification	China	2004	Benefit transfer	1587.7	CNY/ha/yr
Water	Water [unspecified]	China	2004	Benefit transfer	580.9	CNY/ha/yr

Source: Ploeg and de Groot (2010)

Following an experimental approach, Sandhu et al. (2008) measured pest control services of organic vis-à-vis conventional farms (Table 4), and they clearly demonstrate the superiority of organic farming in providing pest control services. In another study, they show that diversified farms and multi-crop farms generate larger ecosystem benefits and less disservices compared to mono cultured farms (Sandhu, 2018). Evidences are also available on soil formation and nutrient retention services of organic farms (Gurr et al., 2004; Tilman et al., 2002).

Rice, the staple food crop in India, generates negative as well as positive flows of services. Rice fields are considered a breeding ground for malarial vector (Jarju et al. 2009; Kant and Pandey, 1999; Mishra and Singh, 1997). Rice farming is also blamed for greenhouse gas emission (GHG) and global warming. Nonetheless, there is a two-way linkage between agriculture and climate change[4]. Role of rice fields in groundwater recharge and control of soil erosion and salinity in water aquifers in coastal regions has been documented in the literature (see, Adarsh and Thomas, 2019). Recent studies also show that submerged rice fields are actually carbon sinks and not GHG emitters (Bhattacharya et al., 2014; Pathak et al., 2005). Although inconclusive, it seems that ecosystem services of rice farming depend on the duration of water logging and the rate of release of methane gas. An economic assessment of the carbon sequestered from rice fields is yet to be attempted.

Table 4. Pest control services

Type of service	Period	Organic farm	Conventional farm
		Mean (SE)	Mean (SE)
Aphid predation	November 2004	18.91 (6.39)	2.37 (0.84)
	January 2005	25.9 (5.19)	0.97 (0.52)
Fly egg predation	November 2004	5.25 (4.74)	3.86 (1.36)
	January 2005	34.08 (3.19)	1.56 (0.86)

Source: Sandhu etal. (2008)

Likewise, livestock are blamed for GHG emission. Nonetheless, in the mixed farming systems, as in India, livestock derive their energy requirement from crop residues and in turn provide energy for crop production in the form of dung and draught power that generate several positive services. Dikshit and Birthal (2010) estimate that if an equal amount of feed energy derived from crop residues has to come from cultivated fodders, the country would require an additional 40 million hectares of land. Use of dung (40% of the output) as domestic fuel saves an additional 1.6 million hectares if fuel-wood is used instead. Rest of the dung is used as manure-and adds 1.22 million tonnes of NPK to soils.

Kumar et al. (2019) made an attempt to quantify economic contributions of different ecosystem services from Indian agriculture. In absence of local monetary values, they used global averages of the values of different ecosystem services. According to their estimates, the invisible ecosystem services account for 62% of the total economic value of agriculture in India (Table 5).

Nonetheless, there are some concerns regarding reliability of the global averages of economic values of ecosystem services and their applicability in Indian context or for that matter in any other developing country. Although, the global averages provide an indication of the potential of ecosystem services in effecting a change in the incentive structure or policy stance, these cannot be relied upon for deciding compensation for providers of these services, i.e., farmers.

[4]https://www.pub.iaea.org/MTCD/Meetings/PDFplus/2012/cn191/presentations/PDF%20Session%204/Wassmann_200.pdf

Table 5. Economic contribution of India's agri-ecosystem services

Ecosystem service	Value($/ha/year) 2007	Value (Rs/ha /year) 2017
Food	1361	24171
Water	167	2966
Raw materials	61	1083
Air quality	170	3019
Climate	777	13800
Waste	222	3943
Soil fertility	281	4991
Pollination	22	391
Genetic diversity	726	12894
Recreation	53	941
Total value	3839	68180
Non-marketed value = total value – (food + raw material + recreation)	2364	41985
Non-marketed as % of total value	62%	

Source: Kumar et al. (2019)

- Most of these estimates are from the agricultural systems of the developed countries, that are much different from India's agricultural system–in scale of production, production portfolio, and technological, agronomic and management practices.
- These estimates are based on limited studies and for a narrow range of cropping activities and crops, and have been extrapolated for the entire agricultural sector without any consideration of the diversity of crops and agronomic practices that matter in the flow of ecosystem services, positive or negative.
- Most of the evidence relates to positive flows, neglecting the negative flows.

These concerns point towards the need for a comprehensive documentation of ecosystem services and their scientific evaluation, for both positive and negative flows, for monetisation so that farming communities can be compensated for the inviable services they provide to the society at no cost

4. PAYMENT FOR AGRI-ECOSYSTEM SERVICES

Payments for ecosystem services(PES) are the payments to individuals (in our case farmers) in exchange of their positive contributions to the society through management of natural resources and other cropping activities. Taccono (2012) defined PES as a transparent system *for the additional provision of environmental services through conditional payments* *to voluntary providers.* In contrast to the 'polluter-pays principle' of environmental taxation, PES is based on the 'beneficiary-gets principle', which is usually applicable in case of non-marketed environmental benefits. There is also a situation when the markets for ecosystem services are inefficient or the local opportunity costs of their conservation are larger than the local benefits but less than the global benefits. In such a situation, the system of payments is mediated or facilitated by the governments or non-governmental organizations.

There are strong arguments for implementation of PES in agriculture. One, agriculture is inherently risky, and farmers' frequent exposure to climatic shocks restricts realization of the full potential of improved technologies. Similarly, higher market risks result in sub-optimal pricing of agricultural produce. Additionally, institutional mechanisms for risk management are either absent or underdeveloped. Therefore, the need to compensate farmers for ecosystem services they provide to the society through agriculture cannot be undermined. Two, ecosystem services are under threat, and the opportunity cost of alternatives is not very high. Hence, it is important to preserve ecosystems through provision of monetary incentives to farmers. Three, there are locations that are ecologically-degraded to an extent that these can no longer support livelihoods of their inhabitants. This calls for arresting their further degradation and efforts for rejuvenation through monetary support to their users. Finally and more importantly, farmers provide a range of non-marketed ecosystem services that are public goods, and are available to the society at zero marginal cost. Farley *et al.* (2010) from an extensive review of literature conclude that *"of the five mechanisms— prescription, penalties, persuasion, property rights and payments available for ensuring the provision of ecosystem services — only payments are likely to be effective".*

In most developing countries, agriculture is practiced by smallholders, and because of a lack of alternative income opportunities they undertake intensive cultivation of land even beyond its carrying capacity. For instance, about half of India's population depends on agriculture, and its average income is just one-fifth of the national average (Birthal et al., 2017). If farmers are compensated for the ecosystem services they provide to the society, they will have incentives for the adoption of technologies and practices that contribute towards conservation of natural capital. Such a compensation for ecosystem services may lead to optimization of agricultural land-use and other resources, reduction in cost of production and improvement in farm profits. Besides, it would contribute towards improving quality of food and other agricultural commodities and ensuring better health and nutrition to the population.

Implementation of the system of PES involves several steps, the most crucial being assigning monetary values to ecosystem services for deciding size of the compensation and budgetary requirements for financing the PES schemes. Figure 4 explains steps of a PES system.

There is an on-going debate that supposedly views valuation of ecosystem services and

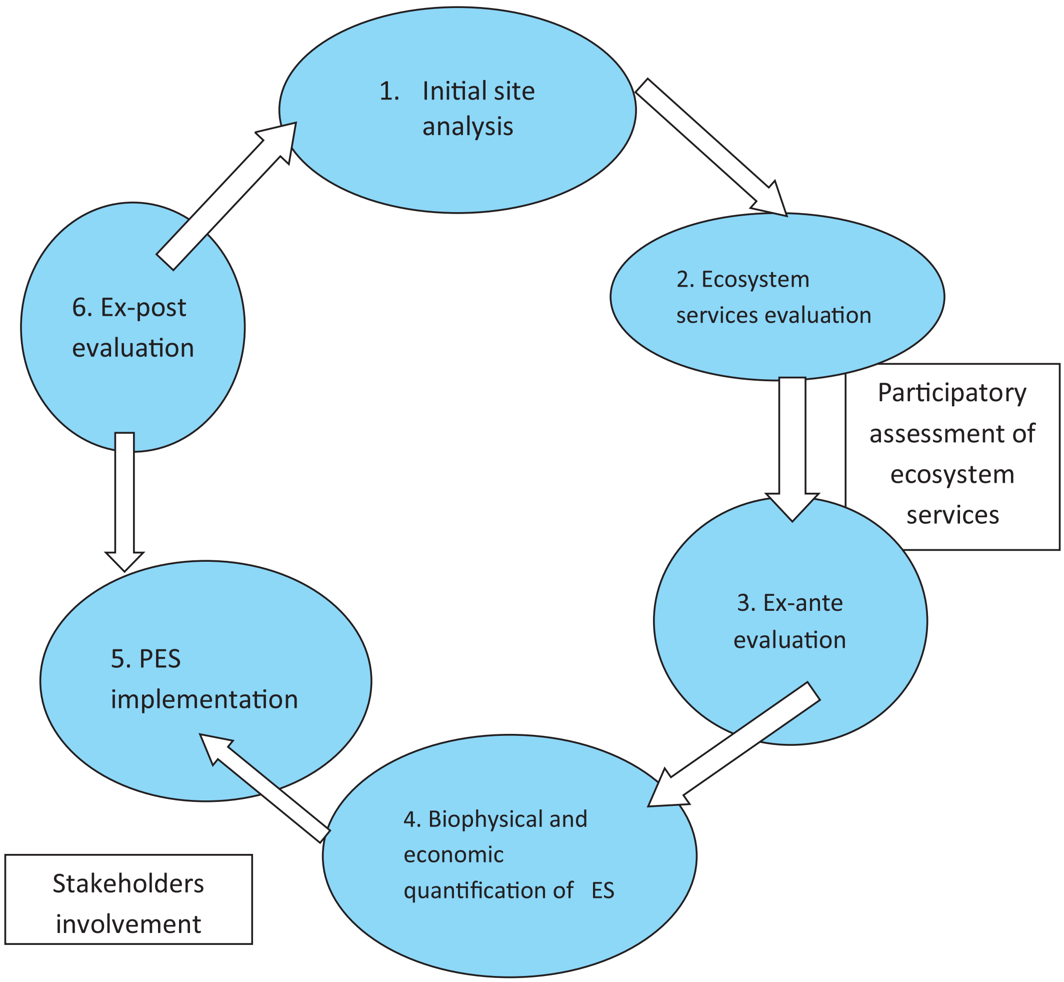

Figure 4. Steps in operationalizing PES,
Source:https://www.mdpi.com/2071-1050/10/3/665

their payments as *commodification* of virtues of the nature. However, Costanza (2006) argues that this critique is largely misplaced as one understands the context and multiple potential uses of ecosystem services. Monetisation of ecosystem services does not mean that these should be treated as private goods for trading in private markets. Most ecosystem services are public goods or products of common assets that cannot (or should not) be privatized.

In 2017, the Government of India had set a target of “Doubling Farmers’ Income” by 2022. Since then, the prospects and challenges in achieving the target have been intensely debated, and a common inference emerging from such debates is that in absence of strategic investments and innovations it is difficult to achieve the target in such a short period. Can a compensation for ecosystem services help improve farmers' incomes? If the estimates in Kumar *et al.*(2019) are to be believed and transformed into an incentive structure, then achieving target of doubling farmers' income is not impossible.

However, valuation of ecosystem services and their mainstreaming in agricultural policy is a challenge. For long, Government of India has been providing several incentives to farmers, in terms of input subsidies and output price support. Often, these are arbitrarily decided from the political economy perspective, and not from the perspective of conservation of natural resources essential for efficient and sustainable development of agriculture.

The need is to take a step towards valuation of ecosystem services that farmers provide to the society through agriculture at zero marginal cost. A beginning can be made with an ecosystem service for which the bio-physical parameters are available and are amenable to monetisation. For instance, the available information on biological nitrogen fixed by leguminous crops or supplied through incorporation of crop residues in the soils, can be assigned a monetary value using market price of the nitrogenous fertilizers. Gradually, one can move towards monetisation of other ecosystem services. Such a valuation serves as an empirical basis for policymakers in deciding the compensation for invisible benefits of agriculture or for farmers to justify their claims on such benefits they provide to the society at zero marginal cost.

Further, in the regime of globalization the domestic market support to agriculture is conditional on the extent to which it does not distort the global market. In the international trading organizations, as WTO, there are often allegations and counter-allegations by the member countries regarding the size of the market support provided to agriculture through output price support and input subsidies. The ecosystem services conserve environment, and compensating farmers for these is not distortionary of the global market. The PES, thus, qualifies for notification under the green box provision of WTO.

Nonetheless, there are arguments and counter-arguments. One of the main arguments is that ecosystem services are public goods, and assigning monetary values to these may lead to their *'commodification'* which is akin to creating private benefits. Further, there are other issues regarding their valuation,payments and trade. A few of these are:

- Who will value ecosystem services?
- Where are the markets for ecosystem services?
- Who are the stakeholders in the market?
- How efficiently the markets for these services will function?

These are the larger issues that need to be addressed comprehensively. Yet, there are counter-arguments too. Unlike other ecosystems the agricultural ecosystem is man-made, and, therefore the farming communities that provide ecosystem services need to be compensated for their contribution towards conservation of nature. With precise delineation of ecosystem services, it is possible to subject these to a monetisation process, and subsequently develop markets for these as for the markets for carbon trading.

5. RECOMMENDATIONS

Ecosystem services from agriculture have not received as much attention of the scientific community, economists and policymakers as of the ecologists and environmentalists. Nonetheless, given the pace of degradation of natural resources, ostensibly due to intensification and commercialization of agriculture, the valuation of ecosystem services from agriculture and allied activities is required so as to effect a change in policy stance or incentive structure for sustainable food production and sound ecosystem health. This assumes importance given the India's targets of reducing greenhouse gas emission by 33-35% and restoration of 26 million hectares of degraded lands by 2030 as part of the 'Sustainable Development Goals' set by the United Nations.

There are inherent difficulties in monetisation of ecosystem services primarily because of the lack of scientific information on their bio-physical parameters required for their monetisation. In view of this the following suggestions merit attention of stakeholders interested in sustainable development of agriculture and conservation of ecology.

(i) Monetisation of ecosystem services requires reliable information on their bio-physical parameters from several disciplines of agricultural science. Hence, the scientific community must be attentive to the need for generating basic information required for monetisation of agri-ecosystem services.

(ii) The economic incentives that triggered growth in agricultural productivity have over time become less relevant, affecting sustainability of agricultural production systems and inter-generational equity. This suggests the need to link agricultural incentives with conservation of ecosystem services. To begin with, only those ecosystem services may be considered for monetisation for which reliable information is available on the bio-physical parameters required for monetisation; for example, the biological nitrogen fixation by legumes. Gradually, the existing incentive structure can be transformed as a package of 'payments for ecosystem services' targeting the key activities related to the conservation of land and water resources, and the adoption of water-efficient crops and agronomic practices.

(iii) At present, the income support or incentives to farmers are decided arbitrarily from a political perspective, ignoring the ecological concerns. Monetisation of ecosystem services will provide an empirical basis for devising regionally-differentiated income support systems for farming communities. For the purpose, it is important to prioritize regions and agricultural activities for implementation of PES. An important consideration here should be the relative importance of economic incentives in influencing the resource use decisions. For example, if power subsidy has a larger negative effect on groundwater extraction, then the scheme for payment for water conservation should be the priority.

(iv) The system of payment for ecosystem services is likely to create incentives for the adoption of technologies and practices that contribute to conservation of natural capital including land, water and forests, and are essential for maintaining inter-generational equity in their use. In the long-run, it is likely that PES may lead to reduction in cost of production and improvement in farm profits and resilience of agriculture against climate change. Hence, it is important to invest in resource conservation research and extension system for transfer of the resultant technologies and practices.

(v) From the perspective of international trading system, i.e., WTO, the system of support to farmers based on ecosystem services does not cause market distortions, and fully complies with the 'green box' provisions of WTO that allows the governments to provide unlimited support to agriculture and agriculturists. The future agricultural schemes should, therefore, be formulated taking into consideration the ecological services and their budgetary requirements.

(vi) Sufficient funding is required for implementation of PES system. There are ways to fund PES. Initially, the local governments can provide direct benefits, may be arbitrarily decided, for some ecosystem services; for example, for nitrogen fixation by legumes. Funds from developmental programs (*e.g. the Mahatma Gandhi National Rural Employment Guarantee Scheme*) can be utilized by mainstreaming these into agricultural programs. Subsequently, the governments may involve private sector for financing PES schemes to ensure that the services on which their business depends are not at risk of disappearing.

(vii) Finally, it is important to develop markets for ecosystem services. This is a difficult task but not impossible once the ecosystem services are monetised. Markets for ecosystem services can be developed on the lines of market for carbon credits.

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