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Addressing rural decline by valuing agricultural ecosystem services and treating food production as a social contribution

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Abstract: Agriculture, the planet's principal anthropobiome is faced with the problems of both its economic trivialization in terms of its relative contribution to GDP, and environmental degradation resulting from the replacement of ecosystem processes with external applications of nutrients and pesticides. Here we discuss (i) various dimensions of these problems in view of the rural decline in developing countries particularly India where landholdings are generally < 1 ha, (ii) and explore the possibilities of enhancing natural ecological elements in crop fields, and payment for agricultural ecosystem services to improve the economy of rural areas and global environment. We argue that (i) the enhancement of natural ecological elements in agricultural ecosystems would contribute to the sustainability of agriculture and flow of various ecological services; (ii) the traditional subsidies to agricultural inputs should be replaced with payment to farmers by considering food production as a kind of social service, (iii) additional economic pathways out of poverty that are not restricted to agriculture would be required to make rural life viable and attractive. The payment for food production as a social service would help small farmers, who are not benefited by traditional subsidies.

Key words: Anthropobiome, GDP, developing countries, environmental problems, India, subsidies.

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Introduction

Because of the excessive focus on "inputs" and "yield maximization", agriculture areas have become source of environmental problems all over the world (Conway 1997). For example, uncontrolled use of pesticides in agricultural fields is responsible for the mortality of wild animals associated with agroecosystems, decreased populations of pollinators, human health risks from pesticide residues on food, and their leaching into water bodies. Nutrient run off from agricultural fields are responsible for anoxic condition in water bodies, and the depletion of underwater vegetation in them, and nitrate contamination of drinking water. Air pollution due to burning crop residues is common in many areas (Conway 1997; Lichtenberg 2004). Agricultural activities have heavily impacted global nitrogen cycle, water resources, and carbon budget of the terrestrial ecosystems. There is a huge environmental cost associated with industrial agricultural activities, which is borne neither by producers nor by consumers. In the United States of America (USA) the cost of damage

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associated with agriculture to people, ecosystems and clean up processes generally remains above $1000 billion per year (Tegtmeier & Duffy 2004).

Nearly 75 % of the 880 million people living on less than $ 1 a day occupy rural areas (WDR 2008). World over, the relative economic importance of agriculture, measured as its contribution to total GDP, has been continuously declining for last several decades (Kumar & Muradian 2008). The ongoing process of economic globalization excludes small farmers (most of which live in agricultural villages of south-east Asia and Africa) from the market economy. The small farmers of developing countries are also affected by heavy subsidies to farmers of developed countries. Economic marginalization of agriculture can lead to food insecurity, particularly in rural areas of the world where live 70 % of 850 million food insecure people (Molden 2007). The environmental degradation and economic marginalization have resulted in a rural decline in developing countries which forces people to migrate to cities, many ending up living in slums with crowded "jhuggies" (make-shift houses generally made up of rags, tin pieces, bamboos, and other similar materials) without proper facilities of drinking water and sanitation. Migration is not always internal, labour flow from less developed to more developed countries for underpaid agricultural work is common. Wealthy countries are greatly benefited by this rural-to-rural migration of poor people (Kumar & Muradian 2008).

India's impressive current economic growth rate can provide a comfortable living in cities for only a small fraction of its 700 million primarily unskilled rural population in next decade or so. The social and economic devaluation of life in rural areas leads to degradation of lands and resources, which results in more migration (Zamora & Foladori 2006). There is a need to innovate new approaches to define economic functions of rural world.

There are some indications that giving value to ecosystem services could contribute to environmental conservation and sustainable development of rural areas (Borner *et al.* 2007). In recent years many countries have achieved, at least some success in protecting forest and biodiversity by educating people about their importance in providing life supporting services (Daily 1997; Singh 2008), though from the market economy stand point forests are not of much importance, and maintaining them can have huge opportunity costs. A similar initiative may be required to strengthen sustainable agriculture and rural life. There is a scope for storing carbon in agricultural soil, and thus mitigating global warming (Ogle *et al.* 2005). How to reduce rural poverty and increase food production in an environmentally sustainable way is a big challenge in most developing countries, particularly when climate change is going to affect almost all aspects of anthropogenic systems.

In this article we review and discuss various dimensions of rural crisis and its consequences, relationship between GDP and contribution of agriculture across the countries of world, the scope of enhancing ecological elements in agriculture, and giving recognition to food production as a special service and other life supporting ecosystem services that emanate from agriculture. Its objectives are to discuss the complexity of environmental and social problems associated with agriculture, and to analyse the scope of giving economic incentives based on them as a strategy to improve rural life. The focus of article is on problems of developing countries, particularly India. However, the idea of promoting natural ecological contents in agriculture applies to all regions of the world.

Agriculture: the principal anthropobiome

Biodiversity of nearly 75 % of the ice-free terrestrial surface of the world has been fundamentally altered by human activities (Foley *et al.* 2005). Recognizing this, Ellis & Ramankutty (2008) have divided the terrestrial ecosystems into several anthropogenic biomes. The human interaction with ecosystems can be indicated by human population density. Across the population density range on the earth, from areas with inconsequential population (< 1 person km^{-1}) to high population density areas (> 100 persons km^{-1}), agriculture and modern transportation have brought about varying changes over the years in interaction between humans and ecological processes.

Nearly, one third of Earth's ice-free land area (about 5 billion km^2) consists of cultivated and populated anthropobiomes which include dense settlements, villages, croplands and residential rangelands (Ellis & Ramankutty 2008). Consisting of several types of villages, croplands, and rangelands, these anthropobiomes account for about 45 % of terrestrial net primary productivity. Much of India, south Asia and south-east Asia are occupied by villages, while rangelands and

croplands are the main features of the Americas, Australia and Central Asia. Of the total global population 40 % live in dense settlement biomes, 40 % in village biomes, 15 % in cropland biomes and the remaining 5 % live in rangeland biomes (Ellis & Ramankutty 2008). These agriculture areas have natural elements in varying degrees. Rangelands all over the world have several extensive plant communities, while industrial agriculture in the USA is dominated by large mono-cultures. The Gangetic Plains in the south of the Himalayan ranges represent one of the most important village based anthropobiomes of the world. The region supports about 500 million people with density ranging between 478 km^{-2} and 1,102 km^{-2} (as per 2011 census).

An analysis of problems associated with agricultural production

The present day agriculture is confronted with several problems. First, its proportional contribution to GDP is declining with increasing economy, consequently food production which is so important for humans is becoming a sort of burden in a narrow economic sense point. Second, while green revolution substantially increased food production in developing countries, like India, economic gains of individual farmers became unattractive after a few years because of very small land holdings (generally < 1 ha). Third, the industrialized way of food production, which is detached from basic ecological processes, has become a major source of environmental degradation. Fourth, pressure on agriculture system to cater to the diverse human needs is on a rise. Fifth, climate change is going to adversely-affect food production in tropical areas, particularly in highly populous southeast and south Asia.

Economic trivialization of agriculture

The relationship between GDP and relative contribution of agriculture to it at the global level shows that as GDP begins to rise, the agricultural contribution declines (Fig. 1). In other words, most of the recent spectacular economic growth in several developing and transforming countries is due to growth of manufacturing and service sectors, and primarily agricultural regions remain poor. From primarily an agricultural economy until the 17th century, the world economy has now a dominant role of service and industry sectors (current contribution to the global GDP being service 64 %, industry 32 %, agriculture 4 %). In developed countries such as USA (service 78 %, industry 20.4 %, and agriculture 0.9 %) the proportional contribution of agriculture to GDP is negligible. Though agricultural economy still contributes substantially to GDP in the most populous Asian countries, namely China (10.01 %), India (13.7 % in 2012 - 13), Indonesia (13.11 %), Pakistan (22.0 %), and Bangladesh (19.9 %), the declining trend is sharp. The World Bank data (2008) on Asia and Pacific region indicates that its traditional agriculture economy has been losing ground to service industries for several years. Its contribution to GDP fell from 23 % to 16 % from 1972 to 1999, while the contribution of service sector rose from 43 % to 50 %. The contribution of agriculture to GDP in India too has been continuously declining for last two decades (from 30 % during the 1990s to 13.7 % in 2012 - 13), but it accounts for about 60 % of employment (Table 1).

Connection between poverty and agriculture can be seen also at a state level in India, primarily agricultural states such as Uttar Pradesh and Bihar, being among the poorest. Though causes of poverty are many, the states with fertile land and dense populations do face several obstacles while diverting their agricultural lands to industrial use because of the dependence of so many people for food and employment. Socially, it is much more difficult to establish a factory in a productive agricultural and densely populated area than in a marginal area. Partly because of it, the largely agricultural states like Bihar have about 4.7 times lower GDP than many advanced Indian states (Ghosh 2001). The economic diminution of agriculture without progress in other sectors in rural areas has led to stark social inequalities, rural and urban divide, and problems of law and order. Of the 850 million food insecure people of the world in 2003, 70 % lived in rural areas (Molden 2007). Marginalization of agriculture as an economic sector is likely to worsen food insecurity. GDP growth from agriculture is said to benefit the poorest more than GDP growth from other sectors up to a point (Kumar & Muradian 2008) (but even this is not a general rule). In China, the growth originating in agriculture was estimated to be 3.5 times more effective in decreasing poverty than growth in other sectors (WDR 2008), but it was not enough to stop rural migration. Most of Indian farmers have so small land holdings (Table 2) that agriculture alone cannot provide economic security to them. Much of agricultural subsidies serve the interest of rich farmers, who are not many in India and other south and south-east Asian countries,

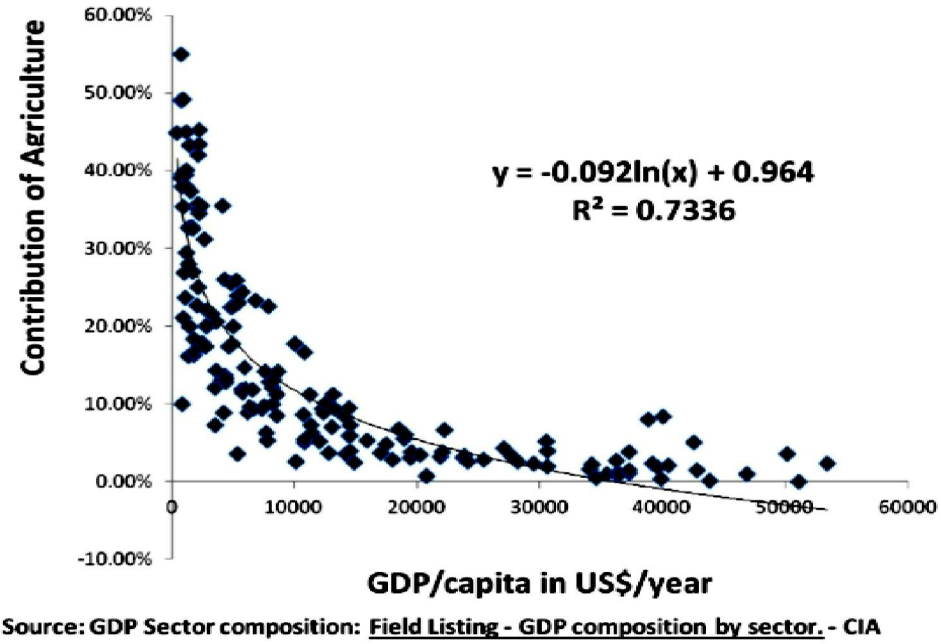

Fig. 1. Relationship between GDP and contribution of Agriculture to it across countries of the world.

Table 1. Position of agriculture in India in comparison to other economic sectors.

	% Contribution by			
	Agri-culture	Industry	Service	Year
GDP ($ 3.319 trillion, PPP 2008)	17.2 (13.7 % in 2012-13)	29.1	53.7	2008
Labour force (523.5million)	60	12	28	2003

Table 2. A comparison between developed and developing countries with regard to socio-economic condition of agriculture.

Country type	Proportional contribution of agriculture		
	GDP	Employment	Income of individual farmers
Developed Country (e.g. USA)	Negligible and stable (< 1 % in USA)	Very small (< 1 % population quite common)	High, largely because of large land-holdings, and subsidies
Developing country (e.g. India)	Still substantial (17.2 %), but declining	High (about 60 % popu-lation in India)	Low, largely because of small land holdings (generally < 1 ha)

and industrialists who produce chemicals and seeds. Subsidies in India are nearly four times greater than public investment in agriculture, but this has not stopped farmers' suicides. The average land holding size in India's most populous state Uttar Pradesh for 90 % of farmers is about 0.5 ha, which generally enables one to earn about US$ 600 per yr or less than US$ 2 per day. It is possible for smallholders to market of their high value products, but growth in their incomes remains unattractive (WDR 2008).

Environmental problems

The environmental problems of agriculture should be analyzed in view of the crisis of food shortage of early 1960s in Asian and African countries. The food shortage was overcome by a technological package based on massive external inputs and crop improvements, often referred to as green revolution in case of India and some other countries. By increasing yield the green revolution saved marginal lands and many forest areas from agricultural conversion (Evenson & Gollin 2003). At the same time it has greatly separated agriculture from ecology (Roberston & Swanton 2005) by replacing ecosystem processes with external controls. For example, nutrient delivery and pest suppression mechanism of ecosystems were replaced with external application of fertilizers and pesticides, respectively. Modern

agriculture is a major source of nutrients that cause eutrophication of water bodies, aerosols that contaminate atmosphere, pesticides which are serious health problems for humans, birds, fishes and several other species of native fauna, and greenhouse gases that cause global warming (Flynn & Smith 2010). Agricultural activities promote the spread of invasive alien species (Perrings 2001). The environmental problems resulting from various agricultural activities can be listed as following: (a) those affecting primarily abiotic components-soil erosion, depletion of soil nutrients and organic matter reserves, salinization and alkalinization, pollution of water systems, accumulation of toxic metals in soil and emission of green house gases and air pollution; and (b) those affecting higher trophic levels i.e., natural predators of agricultural pests, pest resurgence, genetic resistance to pests, depletion of wildlife, spread of invasive alien species, weakening of natural control mechanisms, and loss of pollinators and other friendly organisms. Suitable lands for agriculture, particularly pasturelands are getting degraded because of the spread of invasive alien species all over the world (Dar & Reshi 2015; Pimentel *et al.* 2000).

Mounting pressure on agricultural land

Pressure on existing agricultural land is on increase because of several factors. In past, livestock were parts of the traditional agriculture raised around crop fields. With increased meat demand, improved transport and technological changes in production, the entire system of meat production, and associated resource use and effluents discharge have dramatically changed (Galloway *et al.* 2007). It is estimated that about 5 g of vegetable material is required to produce 1 g of meat (Galloway *et al.* 2007). Annual global meat consumption increased from about 10×10^6 t (~ 10 kg capita^{-1}) at the beginning of the nineteenth century to 73×10^6 t (~23 kg capita^{-1}) by 1961 and to 243×10^6 (~40 kg capita^{-1} global average, and 80 kg capita^{-1} in developed countries) in 2005 (Galloway *et al.* 2007). Interestingly, global meat trade is growing even faster and several developing countries, such as Mexico, Malaysia are important net importers. Another important feature is that the production of non-ruminants (pigs and chickens) has increased much faster than of ruminants (cattle, sheep and goats which are primarily grazers). Nearly 75 % of non-ruminant feed consists of cereals and oil seed-based concentrates, produced industrially. While ruminants feed is forage grown on non-arable land, non-ruminant feed is grown on land used to grow food from humans. Thus, the non-ruminant meat production leads to conflicts with other potential uses of land, and the resources used to produce it, namely fertilizers, pesticides and water.

Agricultural crops, such as sugarcane and maize are now also being grown to produce bio-energy in Brazil, the USA and other countries. Some of them are major exporters of food grains. Obviously, these countries would have less amount of food to spare for others. Bio-fuel production (e.g., ethanol from sugarcane and maize) in several African countries due to the demand from wealthy countries could impair their food security seriously (Muller *et al.* 2007). The dependence of a country on import of food can be risky in a warming world as it is predicted to encounter more frequent and intense drought, flood, and other climatic disturbances. On the other hand, several countries are tempted to import more and more food, as economically it is advantageous to invest in other economic sectors than agriculture. The exceptionally high economic status of Singapore is partly because it does not grow food, and is able to put its land to economically more productive uses.

Urbanization

A major consequence of economic trivialization of agriculture is uncontrolled growth of urban areas, which typically results in a higher per capita consumption of energy and other resources, the production of more waste, and damage to ecosystem functions (Alberti 2005). According to an estimate, 1.7 billion new people will live in cities because of population growth and rural to urban migration in next 25 years, mostly in developing world (UNPD 2005). The resultant increased use of fossil fuels will have global warming implications. Urban growth in developing countries will be a major debacle to a path of sustainable development (McDonald 2008).

While urban growth in most developed countries has now stopped (e.g., at 82.4 % population in USA and 72.2 % population in Europe), massive urbanization has to take place in coming decades in Asia (in 2011 31.3 % of population in India and 53.7 % of population in China were urban) and Africa (38.3 % urban). In China the number of cities has increased from 69 in 1947 to 223 in 1980 and 670 in 2008 (Normile 2008). China has 89 cities with 1 million population each,

Table 3. A comparative account of food grain production of kharif (wet summer season) and rabi (winter season) crops in India (average of 5 years from 1998-1999 to 2002-2003).

Food Grain	Area (million ha)		Production		Yield (kg ha^{-1})	
	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
Rice	39.9	4.0	73.3	11.9	1.835	2.972
Wheat	-	26.4	-	71.0	-	2.692
Coarse cereals	22.5	6.5	24.0	6.5	1.064	0.999
Pulses	0.2	11.2	4.7	8.1	0.455	0.723
Total food grains	72.7	48.1	101.9	97.5	1.401	2.029

Total food grain production of all seasons (million tones) 199.4 (230.67, in 2007-2008).

compared to 37 in the USA and 32 in India. In developed countries urban areas account for over 90 % of GDP, compared to less than 50 % is several developing countries (UNPD 2005). This major shift towards urbanization both in terms of population and economic output will enormously affect ecosystem services and biodiversity (McGranahan & Satterthwaite 2003). Moreover, encroachment of agriculture land by urban areas is reducing area available for producing food all over the world (Greene & Herlin 1995).

Climate change effect

About 60 % of the world's ecosystems are already under stress from climate change and other anthropogenic factors (Ellison 2009). Global warming is predicted to reduce crop production in Asia by more than 19 % without CO_2 fertilization effect by 2100 (Cline 2007). In tropical countries temperatures are already close to the upper limit of tolerance ranges of many organisms (Murdiyarso 2000). Land use changes driven by food production and agricultural practices are the sources of green house gases and now agriculture is one of the main areas that are being affected by the climate change caused by these gases. Seasonal crop productivities in India indicate that summer temperatures seems to limit crop productivity in tropical countries even without global warming. India's agronomic yield, 230.67 million tones in 2007 is almost equally divided between 'kharif' (wet summer crops, primarily rice, sorghum, maize, and some coarse cereals) and rabi (winter season crops, primarily wheat, mustard, and pulses like pea, and chick pea) crop seasons, though the area cropped during kharif is about 50 % greater than during rabi (Table 3). Obviously, on per unit area basis kharif yield is substantially lower than rabi yield in spite of the fact that about 80 % of annual precipitation occurs during the kharif months. It could be because of several reasons: summer temperatures are too high for growth, kharif crops have lower allocation to grains, erratic rainfall and frequent droughts (Legesse & Suryabhagavan 2014) and floods during kharif season (during which a larger fraction of agriculture is rain-fed than during rabi season), and warm and wet conditions are conducive to fungal diseases and insect herbivory. The negative effect of high temperature on food grain production in India is going to intensify with global warming. Indian summers are already too hot to allow crops to grow well.

Climate change is forcing countries to produce new energy sources. A new trend is to buy land in poor African countries to produce food and energy. This is a way to exploit natural resources and environment of other countries.

Promoting environmental integrity and ecosystem services of agriculture

Agricultural can be made more sustainable by: (i) reducing external inputs to crop fields, thereby reducing environmental cost of agriculture; and (ii) promoting benefits of ecosystem services to various social groups, and arranging payment in some form for them. Though raising agronomic yield remains a major concern in agriculture, its role in protecting and promoting environmental integrity cannot be ignored (NRC 2003). Agriculture with a higher ecological integrity can reduce both the external inputs that are required to increase agronomic output, and pollution and degradation of adjoining environment.

Is it possible to achieve productivity of modern mechanized agriculture without external industrial inputs and control? Several crops in

modern agriculture remove more than about 200 kg of N ha^{-1} yr^{-1} from soil solution, compared to 6 - 8 kg of N ha^{-1} yr^{-1} for their unfertilized counterparts (Robertson 1997). The dependence on external inputs of nutrients can be substantially reduced by growing legumes, green manuring and composting, particularly in several Asian and African countries where animals are not separated from crop cultivation. Matching the nutrient supply with crop requirement, conserving organic matter in soil so that both nutrients and water are available to crops for a longer period, and developing biotechnologies that enhance nutrient and water productivities of crops (yield per unit water or/and nutrient used) are some of research areas warranting initiatives to reduce the external inputs. There is a lot of scope of increasing agriculture productivity in rain-fed areas, where people are still poor, and water productivity low- e.g., sub-Saharan Africa, Latin America and parts of Asia (Molden 2007). To develop this form of agriculture, however, we need ecological knowledge and necessary social incentives. How effectively we are going to manage both social and ecological components of agricultural systems would decide the future place of agriculture in the human dominated world (Tilman *et al*. 2002). To an extent, it is possible to replace the current form of agriculture, which is a struggle against nature by the one in harmony with it. For example, no tillage agriculture which helps maintaining crop field condition close to nature helps conserving soil carbon and soil biota. Agricultural ecosystems still retain a natural ecological foundation, even in heavily managed crop fields. For example, crops may get up to 50 % of N uptake from mineralized organic matter (Broadbent & Carton 1978), and natural enemies and plant defense strategies, generally keep pests and pathogens in check (Hajek 2004). Nearly 55 % of the world's gross value of food production is driven by natural evapo-transpiration (Molden 2007). Recently Issacs *et al.* (2009) have emphasized the importance of arthropod- mediated ecosystem services in agricultural landscapes of the USA, including pollination (worth US$ 4.5 billion) and pest control (US$ 3.1 billion yr^{-1}). They suggested that since beneficial arthropods require access to pollen, nectar and plants shelter, planting of native perennial plants should be encouraged. Appropriate mixes of native perennial plants can ensure round the year shelter and over-wintering sites for useful insects on a permanent basis. Some perennial plants, such as bushes also provide nesting sites and food for agricultural birds, and reduce erosion and runoff of agrochemicals into waterways. Apart from the production of marketable commodities like food and fiber, agriculture can provide several ecosystem services, such as pollination, removal of pollutants from water and air, carbon storage, creation of habitat for biodiversity, particularly for beneficial insects, and a variety of birds. Many of the ecosystem services are synergistic. For example, the retention of soil carbon in agricultural soil reduces CO_2 emission to the atmosphere, contributes to the retention of nutrients and water in soil, and promotes invertebrate diversity (Lal 2004). In brief, the ecological integrity of an agroecosystem is important, first because it is a source of several services in addition to food, and second it depends on and impacts natural ecosystems around it. An agricultural landscape, particularly in mountains can have recreational values, scenic beauty, and attractions for bird-watchers and eco-tourists. In Indian subcontinent populations of more than 150 birds are associated variously with agricultural landscapes derived from Grimmett *et al.* (2011), which include cultivations and their edges, crops, paddy fields and paddy stubbles, bushes, bamboos and trees around cultivated areas, sugarcane fields, fallows, village and other human habitations and structures (Table 4).

Approaches to increase biodiversity and other ecological elements in agriculture

Two approaches, "land sparing" and "wildlife friendly-farming" have been suggested to seek balance between demand on agricultural lands and biodiversity (Fischer *et al.* 2008; Greene & Harlin 1995; Waggoner 1996). The land sparing approach focuses on obtaining high yields from intensively cultivated relatively small areas. This allows the preservation of biodiversity-rich areas near cultivated areas. In a wildlife-friendly system the agricultural area itself is used to conserve biodiversity by retaining, as an example, scattered trees, remains of native vegetation, and hedgerows along field margins. In this, agricultural yield per unit area is relatively lower, hence a large area is cultivated, leaving not much land in nearby to preserve diversity.

In land sparing system agriculture is industrial in style, striving for maximum economic efficiency and individual fields are large. In a wildlife friendly system, individual fields are small, landscapes are with complex topography

Table 4. Agricultural habitats and a few examples of their birds in the Indian subcontinent (derived from Grimmett *et al.* 2011).

Habitat	Examples of birds
Reed beds, damp grassland, paddy fields, paddy stubbles	Paddy field warbler (*Acrocephalus agricola*), black-browed reed warbler (*A. bistrigiceps)*, water pipit (*Anthus spinoletta*), starlings (S*turnus* spp.), common snipe (*Gallinago gallinago*), crakes (*Porzana* spp.), comman crane (*Grusgrus*)
Dry cultivation, grassland, thorn scrub, bushes	Silver bill (*Euodicemalabarica*), scaly- bareasted-munia (*Lonchura punctulata*), shrikes (*Lanius* spp.), redstarts (*Phoenicurus* spp.), Indian robin (*Saxicoloides fulicatus*), bulbuls (*Pycnonotus* spp.), larks (*Calandrella* spp.), buntings (*Emberiza* spp.)
Habitations, cultivations around them	Black drongo (*Dicrurus macrocereus*), large cuckooshrike (*Coracina macei*), Indian pea fowl (*Pavo cristatus*), sparrow (*Passer* spp.), Black winged kite (*Elanuscaeruleus*), falcons (*Falco* spp.)
Sugarcane fields, fallows	Swamp francolin (*Francolinus gularis*)
Cultivation with scattered trees and wooded areas	Large cucko shrike (C*oracina macei*), myna (*Acridotheres* spp.), Indian roller (*Coracias benghalensis*), Common hoppoe (U*pupa epops*)
Alpine pastures, cultivation	Red-billed chough (*Pyrrhocorax pyrrhocorax*)

Table 5. Forces that decouple agriculture from its environmental support systems and steps required to address them (developed from Robertson & Swanton 2005).

Decoupling forces	Corrective steps
Subsidies that promote excessive production of single commodity	Promote agricultural ecosystem services and develop knowledge about impact of different management practices on them
Incentives that reward externalizing environmental costs	Give economic incentive for ESs emanating from agricultural ecosystems, and reduction in pollution from them
Pressure to minimize restrictions on uses of resources	Educate about environmental costs, and benefits of environmentally sound agricultural practices
Carbon sequestration in soil of agriculture system still not a part of Kyoto Protocol	Carry out research on soil carbon sequestration and lobby at COPs
Population growth that seeks inexpensive food	Promote policies that alleviate poverty and thereby reduce population growth and cultivation of marginal lands
Food production is treated like any other economic activity	Treat food production as a special social service
Treating food crises as a regional issue, not a global one	Produce more food in region where environmental costs are low, and send to regions of high environmental cost

ESs = Ecosystem Services.

where use of machinery is limited. Situation in the USA and Australia is of land sparing type, while in CotoBrus region in Costa Rica it is of wildlife friendly type. Most of the Himalayan agriculture in which dependence on community forest for day-to-day living is high is similar to that of CotoBrus. In the Gangetic plains of India most of the land is under agriculture, but the holdings are very small (less than 1 ha per household). The area is intensively cultivated, farmers taking two to three crops annually from a piece of land. Since native vegetation was destroyed several centuries ago, natural vegetation has little scope to establish. However, crop diversity is still somewhat retained (25-30 crop species in about 1000 ha agriculture area is quite common), and planting of bamboos, mangoes, and other trees in nearby areas or field margins is common (Sharma *et al.* 2007). By providing habitat and resources, agricultural areas even in Gangetic plains support several wild animals such as blue bull (*Boselaphus tragocamelus*), jackal (*Canis aureus*), lesser cats and several wetland birds. There is a need to take several corrective measures based on an understanding of forces that have decoupled agriculture from its environmental base (Table 5). Valuing ecosystem services, discovering ways to increase their flows and arranging payment for them are still in very formative state. There is a need to develop ecological knowledge to identify ecosystem services and their biophysical underpinning, and understanding in areas of economics and other social sciences to value them, and put payment in place (Robertson & Swanton 2005). Giving value to agriculture ecosystem services has only recently found a place in research and policy decisions, mostly in developed countries. However, non-market valuation of forest ecosystem service has received considerable recognition during last two or three decades, and that could be applied to agricultural systems with appropriate adjustments. None of the methods applied to valuate ecosystem services (e.g., travel cost method, hedonic price analysis, and averting expenditures) fully capture the total economic benefits, nevertheless monetary values are attractive for public policy as they generate some yardstick for comparison.

A major step in this direction could be to make people aware of agriculture-based ecosystem services. In a study carried out on crop pollination service in Kenya by Kasina & Holn-Muller (2009), it was found that while 99 % respondents knew about bees, only 47 % were aware of the importance of bee pollination in crop production. However, when people were explained the process of pollination and its significance, 98 % were willing to support bee conservation and pay for it. Another form of agricultural ecosystem services which has been researched well is taking measures which reduce pollution in water bodies located around crop fields. In a study in China impact of different crop combinations was seen on water quality of the adjacent lake (Sgobbi *et al.* 2006). The study showed that the combination of agronomic crops, fruit trees and livestock not only increased the farmers' income, it also reduced erosion and suspended nutrient load in the lake. Organic farming is particularly suited to green houses, realizing higher yields, but it results in lower bird diversity and reduced ecotourism (Sgobbi *et al.* 2006).

Another form of ecosystem services associated agriculture is the maintenance of genetic diversity in a form of landraces. Remote regions in Himalaya still have many landraces and wild relatives of crops. For example, Nepal is known to grow about 200 landraces of rice. Though the number of landraces is decreasing rapidly, farmers still grow landraces with superior grain quality, market price, yield and environmental adaptability over a large area (Brush 2000; Poudel & Johnsen 2009).

Policy implications and conclusions

Though subsidies to agriculture have kept on increasing for quite long time, it could not keep people interested in agriculture, even in developed countries where land holdings are large, generally 50 - 100 ha. The decline in the relative contribution of agriculture to GDP throughout the world is a common trend. While individual farmers in countries such as USA were able to protect their economic status because of large land holdings and agricultural subsidies, farmers in many developing countries where landholdings are very small (Table 2), live below subsistence level. Such small farmers helped solving food problems, but they remained economically insecure. As economy grows and service and manufacturing sectors become its principal components, many educated and skilled youth migrate to urban centers, leaving old people and children in the rural areas. How to make agriculture viable enough to attract youth in these circumstances so that rural decline is stopped, is a challenging task. The idea of promoting agricultural ecosystem services can

improve environmental sustainability but its role in income generation will remain limited, particularly in economically less developed countries. In order to establish a reliable market for agricultural ecosystem services, the policy-makers need to pay attention to not only provision and supply of the services, but also to creation of demand such services (Gaehwiler *et al.* 2009). We suggest that producing food itself can be treated as a service, deserving payment. However, this has to be conditional. For example, the amount of food produced by a farmer would be required to be consistent with the potential of the land, and agricultural practices conforming to both ecological and yield increasing principles. The transaction cost of managing these payments and regulations can be huge, but justified on socio-economic and environmental grounds. The food grain produced by farmers is the keystone of several global economic activities, such as trade of value-added food products, meat export, transport, and manufacture of agricultural tools. Only this kind of recognition and incentive can attract younger generation. Often agriculture-based development plans are made keeping in view the attributes of earlier generations while changes that are affecting new generation are generally ignored. Treating food production as a service would be culturally acceptable in many societies where offering prayers before taking daily meals is a common practice. Thus, the food production need to be viewed holistically in terms of selling agricultural goods and adopting agricultural practices that contribute to ecological sustainability. Improvement in quality of river water, increase in population of pollinators, increase in soil organic matter, and production of agricultural goods with no pesticide residue are some of the examples of contribution to ecological sustainability. The farmers could also be encouraged to develop agriculture-based recreation and eco-tourism, or such places could be used as "outdoor" study sites for educational institutions (Lowman & Randle 2009). To have more economic activities based on sound ecological infrastructure is also important to promote social life in rural areas. With more growth of service and industrial sectors and more migration of people, the land holdings may grow enough to become more economically viable.

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