African Crop Science Journal, Vol. 31, No. 2, pp. 239 - 262
ISSN 1021-9730/2023 $4.00

DOI: https://dx.doi.org/10.4314/acsj.v31i2.9

PROSPECTS OF PAYMENT FOR ECOSYSTEM SERVICES: A CASE FOR TEAK AND CASHEW PLANTATION DEVELOPMENT IN GHANA

B. OSEI, S. ABUGRE, E.A. OBENG[1], A.B. AFRIFA, I. OFORI[2] and M.R. ADAMS

University of Energy and Natural Resources, Sunyani, Ghana.
[1]CSIR-FORIG - Council for Scientific and Industrial Research - Forest Research Institute of Ghana
[2]University of Mines and Technology, P. O. Box 154, Takoradi, Ghana
Corresponding author: benfieldosei@gmail.com

(*Received 15 June 2022; accepted 9 March 2023*)

ABSTRACT

Governments and institutions across the globe are strengthening efforts to safeguard ecosystem diversity from deteriorating; while promoting proper conservation management so that ecosystem services are sustainably explored for human benefits. A major challenge that obstructs the success of environmental conservation management efforts have normally been the willingness of individuals and local community members to allocate lands for biodiversity conservation. In order to circumvent these challenges and without limiting human socio-economic needs, payment for ecosystem services (PES) programme was initiated and endorsed by governments as a relevant modality and policy framework to protect and restore ecosystems. Unfortunately, there is paucity of information on this by some countries, such as Ghana. Since its inception, PES has great prospects for especially two economic tree crops, such as cashew and teak. That notwithstanding, the perception of smallholder farmers on ecosystem-friendly practices especially PES for cashew and teak plantation development in Ghana is unclear. Therefore, the present study sought to review the concept of payment for ecosystem, its implications on teak and cashew plantation development in Ghana, as well as to investigate the perception of smallholder farmers on the new development policy. It is clear from this review that the adoption and implementation of PES holds great potential for cashew and teak plantation development in Ghana. Cashew and teak are economic trees which prospects for economic development but due to certain constraints, their potentials from the stand point of PES are yet to be realised in the country. One major weakness of the cashew and teak plantation development is inadequate land and unfavourable tenure systems; apart from the inability of smallholder farmers to successfully develop and implement PES schemes for cashew and teak plantation. It was apparent that PES holds great economic prospects for smallholders in cashew and teak plantation development and that it is multi stakeholder approaches and not business as usual that will not allow us to experience the full benefits from this pursuit. Based on the outcomes of this review, it is recommended that trans-disciplinary research be conducted to evaluate the economic, biological and social implications of adopting PES in plantation systems and consequently effects on agricultural systems.

Key Words: Biodiversity, conservation, tenure systems

RÉSUMÉ

Les gouvernements et les institutions du monde entier renforcent leurs efforts pour empêcher la détérioration de la diversité des écosystèmes ; tout en promouvant une bonne gestion de la conservation afin que les services écosystémiques soient explorés de manière durable pour les bénéfices humains. Un défi majeur qui entrave le succès des efforts de gestion de la conservation de l'environnement a normalement été la volonté des individus et des membres de la communauté locale d'allouer des terres à la conservation de la biodiversité. Afin de contourner ces défis et sans limiter les besoins socio-économiques humains, un programme de paiement pour les services écosystémiques (PES) a été lancé et approuvé par les gouvernements en tant que modalité pertinente et cadre politique pour protéger et restaurer les écosystèmes. Malheureusement, il y a peu d'informations à ce sujet par certains pays, comme le Ghana. Depuis sa création, le PES a de grandes perspectives, en particulier pour deux cultures arboricoles économiques, telles que l'anacardier et le teck. Malgré cela, la perception des petits exploitants agricoles sur les pratiques respectueuses de l'écosystème, en particulier le PES pour le développement des plantations d' anacardier et de teck au Ghana, n'est pas claire. Par conséquent, la présente étude a cherché à investiguer le concept de paiement pour l'écosystème, ses implications sur le développement des plantations de teck et d' anacardier au Ghana, ainsi qu'à étudier la perception des petits exploitants agricoles sur la nouvelle politique de développement. Il ressort clairement de cette enquête que l'adoption et la mise en œuvre de PES peuvent augmenter le développement des plantations d' anacardier et de teck au Ghana. L'anacardier et le teck sont des arbres économiques qui ont des perspectives de développement économique mais en raison de certaines contraintes, leurs potentiels du point de vue de PES ne sont pas encore réalisés dans le pays. L'une des principales faiblesses du développement des plantations d' d' anacardier et de teck est l'insuffisance des terres et des régimes fonciers défavorables ; mis à part l'incapacité des petits exploitants agricoles à développer et mettre en œuvre avec succès des systèmes de PES pour les plantations d' d' anacardier et de teck. Il était évident que le PES offre de grandes perspectives économiques aux petits exploitants agricoles dans le développement des plantations d' d' anacardier et de teck et que ce sont les approches multipartites et non le statu qui ne nous permettront pas de tirer pleinement parti de cette poursuite. Sur la base des résultats de cette enquête, il est recommandé que des recherches transdisciplinaires soient menées pour évaluer les implications économiques, biologiques et sociales de l'adoption de PES dans les systèmes de plantation et, par conséquent, les effets sur les systèmes agricoles.

Mots Clés : Biodiversité, conservation, régimes fonciers

INTRODUCTION

Ecosystem services which are crucial for human survival and well-being on earth are nature's service provisions (Pascual *et al*., 2017). Biological diversity or biodiversity which is central to ecosystems forms an integral component in the maintenance of vital ecological processes (Tilman *et al*., 2006; Mori *et al.*, 2013). However, biodiversity has declined considerably globally due to inappropriate human activity and climate change, leading to degraded ecosystems, lowered viability of the services and ecological functions. This has resulted in detrimental impacts on vital native plant species; and thus declining biological diversity (Scheffers *et al*., 2016; Quijas and Balvanera, 2018). For instance, depleting land of forests which has stripped them, thus rendering them prone to soil erosion, break in water cycles and depletion of water resources, loss of wildlife habitats, and reduced carbon storage in forests.

Rapid deforestation is commonly associated with alterations in the chemical composition of the atmosphere, altered biodiversity as well as depletion of vegetation cover. Given the wide reaching nature of

biodiversity and ecosystems, the discussions have gone beyond the reality of ecosystem depletion into a discourse of adaptive management. In the pursuit of adaptive ecosystem management, reforestation efforts have been central to the ecosystem restorative efforts. This is the point that the discussions traverses into the prospects for PES vis-à-vis economic tree crops plantation development, especially for cashew and teak tree plantations. The two tree crops have bright prospects for PES that if rightful synergies are harnessed we could attain socio-economic, and ecological benefits in equilibrium.

Deforestation occurs when forests are erased off the land to pave way for other purposes such as mineral exploitation, agriculture and infrastructural development. Forests may also be devastated through natural disasters such as floods and wildfires to the extent that the affected area becomes incapable of regeneration. By neglecting their reclamation, such lands are rendered waste resulting in a threatened ecosystem and diminished service provisions. In this situation, a great deal of effort in terms of financial investments and a good policy framework will be expedient in addressing the menace. It is nevertheless explicit that various kinds of anthropogenic activities have impacts on nature in the form of degradation of major ecosystem services, which in recent times has triggered global concern especially by governments across the globe (Pascual *et al.,* 2017).

As a result of this, governments *via* intergovernmental collaboration programmes; have designed a number of key strategies to re-establish degraded ecosystems; while preserving the existing ones. The benefits derived from ecosystems (ES) to humans have been underscored by resource conservationists (Iniguez-Gallardo *et al.*, 2018). Thus, in recent times ESs have fully been integrated into the discourse of sustainable environmental management systems in order to motivate communities to conserve nature's provisions to humans (Van der Horst, 2011; Tacconi, 2012).

In its simplest form, ecosystem services encompass both the direct and indirect benefits that are derived from wild species also referred to as the ecosystems (TEEB, 2010; Iniguez-Gallardo *et al*., 2018; Lappointe *et al*., 2020). In Ghana, there have been some attempts at PES, using various methods including replanting depleted forests, conserving existing natural forests, preserving species within these ecosystems. In tree plantation development, the choice of trees for planting is influenced by a number of factors, namely feasibility, viability and economic prospects of the tree crop.

In the case of Ghana, cashew and teak are among the tree species that have been associated with bright prospects with regard to implementing PES as an ecosystem governance measure. For the Ghanaian situation, available data suggested that cashew and teak trees could be viably used to replant degraded forest ecosystems to restore natural flora and fauna; and to implement PES schemes that will yield social, economic and ecological benefits for humans, leading to sustainable management of ecosystems.

One of the main challenges hampering success in the environmental conservation management effort in Ghana has been contradictions arising between environmental conservationists and ecosystem service actors which include individual landowners or local communities. To circumvent these threats without limiting human socio-economic needs, the payment for ecosystem services (PES) programme was initiated through efforts of governments by prescribing the most expedient modalities or policy frameworks to protect and restore ecosystems.

Since its establishment, PES has been embraced and is being extensively implemented across various countries perhaps due to the numerous ecological benefits the programme offers (Matzdorf *et al.*, 2013, Schomers and Matzdorf, 2013). In Ghana, PES programmes

have been experimented, and some tree species especially cashew, mango and teak have been prioritised in choosing tree crops for managing ecosystems to achieve socio-economic and ecological benefits.

In Ghana, population growth, urbanisation, mineral exploitation, wildfires and several others have flawed the integrity of the nation's ecosystem, thus limiting the beneficial services that can be derived. Deforestation and forest degradation are so alarming with an estimated rate of forest tree decline of 2% annually, which has consequently raised many concerns in relation to the ability to realise national development goals (Oduro *et al*., 2015).

Presently, Ghana's forest cover has declined from about 9,924 thousand ha in 1990 to 7,986 thousand ha (Guuroh *et al*., 2021). With these statistics, the way forward proposed by practitioners has been the need for efforts to reforest degraded forests, and to reclaim degraded lands. A more plausible option that of planting economically viable trees, especially cashew and teak. These tree species are early maturing, offer diverse economic, social and ecological benefits and offer options for attaining sustainable management of natural resource embedded ecosystems.

In Ghana there exist favourable policy frameworks in the form of strategic programmes and projects conducive to sustainable management for ecosystem services (Oduro *et al.,* 2015). National development projects including the Ghana Forest Plantation Strategy 2016-2040 and the forest plantation development are essentially some of the state forest policies enrolled to regenerate old forests and afforest new lands for timber production and environmental conservation enhancement. Teak and cashew are economically important plantation species in Ghana and form an important component of the nation's afforestation programmes.

For the specific case of cashew, there are more ecosystem services to be derived from same for instance beyond wood for fuel and construction, cashew produces cashew fruits, cashew kernel, which can be used to produce cashew cake, candy, biscuits, bread spread, jam, wine, and gin. At the industrial level, the waste material from cracked cashew nuts can be used as biofuel, wood preservative, and polish, thinner. At the construction level, the debris from cracked kernels can be mixed with cement and used to harden ground or wall surfaces. When it comes to teak, organic dye can be extracted from the leaves, seeds can be harvested, the poles derived from the teak logs are used as poles for connecting electricity cables to power homes and industries. The ecological services to be derived from all trees plantations include services as windbreaks, erosion control measures, and carbon sequestration. In all of the known uses of cashew and teak as enumerated, losses of cashew and teak plantations means that all the listed ecosystem services are also lost on us leading to the further deepening of the poverty of smallholders who are direct beneficiaries of these ES.

Since the commencement of the programmes, the teak and cashew plantation development project implementation has been constrained by a number of factors including funding and the willingness of landowners to voluntarily release their lands for forestry and ecosystem management (Ghana Cashew Development Project, 2000).

The payment for ecosystem services policy has emerged and has been adopted for implementation in several countries across the globe (Wunder, 2015). The feasibility of the PES programme as a strategy to protect ecosystems in Ghana, while benefiting from its services has been investigated and severally recommended for implementation. Therefore, the present study sought to review the concept of payment for ecosystem, its implications on teak and cashew tree plantation development in Ghana, as well as to investigate the perception of smallholder farmers on the new development policy.

Ecosystem Services. The term "Ecosystem Service" (ES) was coined to describe the totality of benefits that humans derive from 'natural capital" as human life sustainer (Duraiappah and Bhardwaj, 2007). Such human life needs include self-purification of natural water bodies, flood control, soil erosion control, and hillside protection by afforested areas (Duraiappah and Bhardwaj, 2007).

Since its inception in the 1970s (SCEP, 1970), the concept has grown to include socioeconomic and conservation goals, with its popularisation underscored by reports of the Millennium Ecosystem Assessment (MA, 2005) as well as the United Nations Conference on Climate Change (COP21) (2015). The two international conservation policies have recognised the role of ESs in mitigating impacts of climate change. Many ESs have been assigned economic values to assist decision-makers in making informed choices by attempting to correlate current-*versus*-future costs and benefits, organising and translating scientific knowledge into economics, and articulating the consequences of societal choices in comparable units of impact on human well-being (DeFries *et al*., 2004).

Based on this, the ecosystem service provider (ESP) was developed as a concept meant to identify the constituents of ecosystem that should be managed to achieve a sustained service delivery (Garcia-López and Arizpe, 2010; Quijas and Balvanera, 2013).

Classification of Ecosystem services. Ecosystem services (ES) have been classified into provisioning services, regulatory services, cultural services and support services (Fig. 1). The bottom line, however, is that ES are very crucial to maintaining the ecological balance between economic, social and ecological objectives of society. The next section of the review focuses on the various classification of ecosystem services.

Ecosystem provisioning services. Ecosystem provisioning services occur in different forms such as food, fibre, fuel, timber, water quantity for domestic consumption and farming, farming opportunities like beekeeping, as well as raw

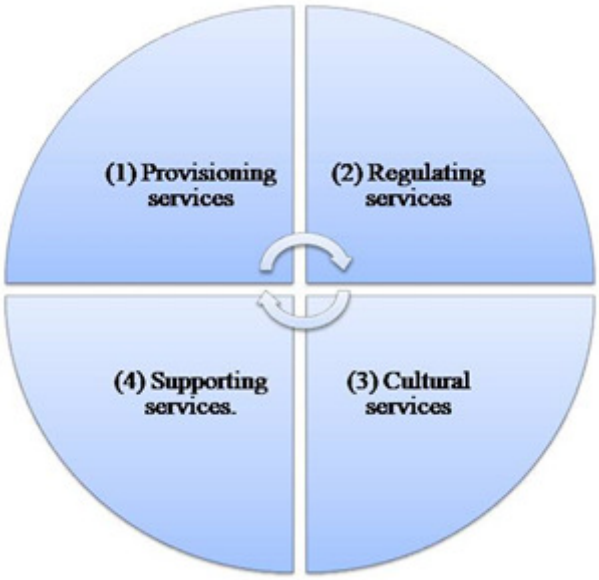

Figure 1. Classification of ecosystem services (Adapted from MA, 2005).

materials of varying forms including firewood, and non-timber forest products which are beneficial to people (Schröter *et al*., 2018; van der Plas, 2019). Provisioning services also consist of plant species that are collected for their medicinal value (Reed *et al*., 2017). Many of the ecosystem provision services are bought and sold in markets. Provisioning services are also directly depended on for livelihood, especially in rural settings (Reed *et al.*, 2017). Generally, diverse agricultural areas such as forestry and fisheries both influence and are influenced by the ecosystem services (Angelsen, 2010; Van Hecken *et al.*, 2012).

Ecosystem regulating services. The ecosystems regulating services act as a regulator of a variety of systems such as climate, air quality, soil erosion, flood and disease control, storms and typhoons, droughts, forest fires, pests and diseases, and air quality (Fripp, 2014). Tree species regulate shades, rainfall, air quality and water availability but are influenced by the local forest systems. Also, ecosystems regulate climate change in the form of storage and carbon sequestration as directly linked to greenhouse gases (Xu *et al.,* 2017). Again, ecosystems play regulatory roles by moderating the occurrence of varying forms of extreme events or hazards associated with prevailing weather conditions including floods, storms, tsunami, volcanoes, landslides and many more (Yan *et al*., 2014; Xu *et al*., 2017; van der Plas, 2019).

By acting as regulating service, the ecosystem characterised by wetlands are significant in water treatments where animal and human wastes are filtered while biological activities break down the waste products. Soil erosion and fertility are vital in crop production and their maintenance implies controlling degradation and desertification. Whereas many plant species intervene in soil erosion, micro organisms generally are involved in decomposition of organic substances and thus maintenance of soil fertility (Quijas *et al.,* 2010). Other regulating service provision of ecosystem embodies the role of organisms in pollination, control of pest and vector-borne diseases (Quijas and Balvanera, 2013). Pollination as ecosystem regulatory service is beneficial to humans in that it increases yield productivity of flowering crops, fibre, fodder, wood, as well as several wild plant species (Kremen *et al*., 2007). Previous studies established that regulatory services are very much appreciated by members who are usually not directly engaged in agricultural activities (Swinton *et al.*, 2007; Díaz *et al*., 2011).

Ecosystem cultural services. There are diverse components of ecosystem which are of cultural significance. Generally, the cultural component of ecosystem services constitutes the non-material benefits originating from the interaction between people and the ecosystem (Quijas and Balvanera, 2013; Reed *et al*., 2017). People normally walk, participate in physical exercise or sports in different environments which contributes to the maintenance of the physical and mental wellbeing (van der Plas, 2019). Generally, ecosystems and biodiversities are valuable for tourism, recreation, and education by virtue of the aesthetic aspirations (Ferraro and Hanauer, 2014; Schröter *et al.,* 2018) and thus, provide numerous economic benefits to countries that are committed to extract the gains.

Ecosystem supporting services. Almost everything required for livelihoods are provided by ecosystem services. Basically, supporting services derived from ecosystems to some extent are considered as ecosystem processes beneficial to humans through the support to one or more of the other services (Quijas and Balvanera, 2013). For instance food, water, raw materials and shelter which are human life necessities are basically a supporting service from ecosystem habitat. Interestingly, habitats are heterogeneous and therefore, each habitat may have unique of broad range of supporting services. One of the most essential

requirements of life success is diversity which is central for the continuity of organisms on which life is depended upon. Generally, ecosystem supports human life through the presence of genetic diversity of its components. Ecosystem supporting services also includes that which supports other ecosystems services like soil formation, and nutrient cycling (Iniguez-Gallardo *et al*., 2018)

Smallholder farmers' perception on ecosystem services. Understanding smallholder crop farmers' perceptions on ES is critical for defining their involvement in multi-scale governance and consequently, in the sustainable management of forests. Perception is a subjective process as individuals will perceive the same environment from a divergent perspective. An individual or a community's attachment of value to an ecosystem is intimately related to perceptions. Usually, members of rural communities rely extensively on ES relative to those in the urban areas. Similar to this is the finding that inhabitants of less developed nations are more reliant on ES than those residing in developed nations (Christie *et al*., 2012). Previous studies on ecosystem conservation also reveal that transparency and trust between ecosystem providers and institutions involved plays a key role in the level of commitment of the former in subscribing to the implementation of the environmental conservation policy (Gross-Camp *et al*., 2012; Wunder, 2013). Depending on factors including location, different people of communities are likely to show a differential appreciation for different ecosystem services and this influences the extent of importance attached to ecosystem conservation management. In a comparative study that sought to determine the perception of people on ecosystem services in southern Ecuador (Iniguez-Gallardo *et al.,* 2018) identified a total of 13 and 12 ecosystem services in Arenillas and Ceiba respectively, with priority for each service differing across the two areas. They further identified two key factors that have influence on how people perceive ecosystem as the "management strategies undertaken in each protected area and the involvement of the different social actors with the reserves". Knowledge about such information based on survey studies among smallholder farmers will play a central role in the effort to improve livelihood through the ecosystem. The agricultural sector in Ghana has over the years been dominated by smallholder farmers who cultivate their food crops on less than 2.00 hectares (MOFA-SRID, 2011). Many households in Ghana just as the case may be across the entire sub-Saharan Africa, continually struggle with socioeconomic constraints. In order to harness agriculture for the full benefit of the population, smallholders crop farmers need to be supported to incorporate plantation activities in their staple crop production systems. Particularly, following the increasing crop vulnerability to impacts of climate change, many plantation species such as teak and cashew have endowed resilience to environmental impositions (Derkyi *et al*., 2018). However, first, smallholder farmers' perception on ecosystem services, especially on value attached to their maintenance must be well investigated.

PAYMENT FOR ECOSYSTEM SERVICES (PES): A SWOT ANALYTICAL OVERVIEW

Following the Earth Summit in Rio de Janeiro in 1992, research interest has since been aroused on matters regarding the impacts of altered biological diversity and species loss on ecosystem and ecosystem functioning (van der Plas *et al.*, 2019). The current state of the global ecosystem degradation is so critical that there has been incessant calls to design or adopt environmentally feasible policy frameworks in safeguarding the numerous ecosystem services (derived benefits) that are depended upon by humans for their wellbeing (Chen *et al*., 2012; Kaiser *et al*., 2021). Nonetheless,

the debate regarding which policy framework is best suited for achieving desired results is always in the discourse on many academic and non-academic platforms (Wu and Qiaoling, 2018; Kaiser *et al*., 2021).

In recent times, the payment for ecosystem services (PES) programme in environmental conservation management has been highlighted (Martin-Ortega and Waylen, 2018; Wu and Qiaoling, 2018; Kaiser *et al.,* 2021). PES is a conditional transaction over well-defined ecosystem services between at least one "seller and one buyer" (Huber-Stearns *et al*., 2013; Fripp, 2014). As a recently emerged strategy, PES was designed to channel investment in environmental conservation management by paying land owners to protect, restore and reclaim ecosystems in the interest of ensuring the provision of some services derived from what nature offers humanity such as clean water, habitat for wildlife, or carbon storage in forests (Jack *et al.,* 2008; Van der Horst, 2011; Brownson *et al*., 2019). The main goal of the PES programme is to protect ecosystems and their associated services along with promoting a sustainable livelihood of people, or communities (Huber-Stearns *et al*., 2013; Engel, 2015).

Under the PES system, land owners voluntarily participate in environmental conservation projects by enrolling their lands (Van der Horst, 2011; Cook *et al.,* 2016; Grima *et al.,* 2016). In its simplest description, the concept of PES proposes a payment to an individual or a community ready to embark on an activity meant to enhance an increasing level of desired ecosystem service (Van der Horst, 2011). Therefore, under the PES, land (resource) owners or ecosystem services providers partake in environmental preservation project to receive an incentive (cash, assistance, material) to undertake environmentally desirable actions and to avoid damaging the environmental resources such as water, soil and wildlife (Fripp, 2014; Van Hecken *et al.,* 2015; Grima *et al*., 2016; Sorice *et al*., 2018; Thompson, 2018).

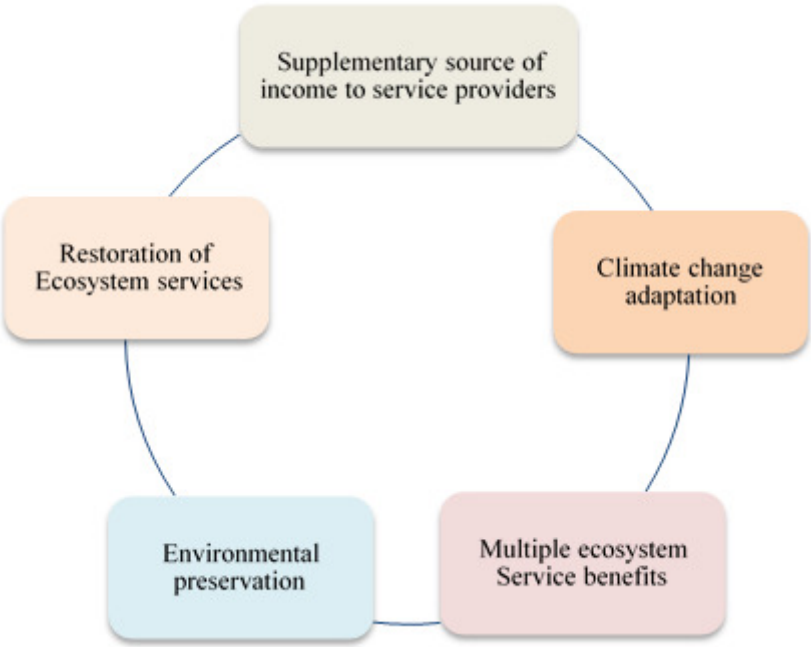

Figure 2. Economic benefits of payment for ecosystem services.

TABLE 1. Research update on payment for ecosystem services

Reference	Research type	Description
Kaiser *et al*. (2021)	Review article	Payments for ecosystem services: a review of definitions, the role of spatial scales, and critique
Brownson *et al*. (2019)	Systematic review	Community based payments for ecosystem services (CB-PES): implications of community involvement for program outcomes
Wu and Qiaoling (2018)	Systematic review	Integrated evaluation of payments for ecosystem services programs systematic review
Salzman *et al*. (2018)	Review article	The global status and trends of payments for ecosystem services
Martin-Ortega and Waylen (2018)	Research article	PES what a mess? An analysis of the position of environmental professionals in the conceptual debate on payments for ecosystem services
Schröter *et al*. (2018)	Research article	More than just linking the nodes: civil society actors as intermediaries in the design and implementation of payments for ecosystem services - the case of a blue carbon project in Costa Rica
Sorice *et al.* (2018)	Research article	Scaling participation in payments for ecosystem services programs.
Thompson (2018)	Research/Original article	Institutional challenges for corporate participation in payments for ecosystem services (PES): insights from Southeast Asia
Lima *et al.* (2017)	Original article (Case study)	Uncertainties in demonstrating environmental benefits of payments for ecosystem services
Hayes *et al.* (2017)	Original article (Case study)	The impact of payments for environmental services on communal lands: an analysis of the factors driving household land-use behavior in Ecuador.
Narloch (2017)	Review	What role for cooperation in conservation tenders? Paying farmer groups in the High Andes. L
Reed *et al*. (2017)	Original research (Case study)	A place-based approach to payments for ecosystem services
Reutemann *et al.* (2016)	Original research (Case study)	How (not) to pay - field experimental evidence on the design of REDD+ payments
Souza *et al*. (2016)	Original research (Exploratory study)	Environmental services associated with the reclamation of areas degraded by mining: potential for payments for environmental services

TABLE 1. Contd.

Reference	Research type	Description
Engel e*t al*. (2016)	Review	Payments for environmental services to promote "climate smart agriculture"? Potential and challenges
Cook *et al*. (2016)	Review	Coordinated service provision in payment for ecosystem service schemes through adaptive governance
Grima *et al*. (2016)	Review(Analysis of published PES cases)	Payment for ecosystem services (PES) in Latin America: analyzing the performance of 40 case studies
Wunder (2015)	Review	Revisiting the concept of payments for environmental services.
Engel (2015)	Review	The devil in the detail: a practical guide on designing payments for environmental services.
Nieratka *et al*. (2015)	Original research (Household survey)	Can payments for environmental services strengthen social capital, encourage distributional equity, and reduce poverty?.
Muniz and Cruz (2015)	Review	Making nature valuable, not profitable: Are payments for ecosystem services suitable for degrowth?
Van Hecken *et al*. (2015)	Review	What's in a name? Epistemic perspectives and payments for ecosystem services policies in Nicaragua
Reed *et al*. (2014)	Review	Improving the link between payments and the provision of ecosystem services in agri-environment schemes
Wunder (2013)	Mini review	When payments for environmental services will work for conservation.
Huber-Stearns *et al*. (2013)	Original article (Review and empirical case study)	Intermediary roles and payments for ecosystem services: a typology and program feasibility application in Panama
Matzdorf et al. (2013)	Review	Institutional frameworks and governance structures of PES schemes.
Muradian (2013)	Review	Payments for ecosystem services as incentives for collective action.
Muradian et al. (2013)	Review	Payments for ecosystem services and the fatal attraction of win-win solutions.
Schomers Matzdorf (2013)	Review	Payments for ecosystem services: a review and comparison of developing and industrialised countries
Chen *et al*. (2012)	Research article	Agent-based modeling of the effects of social norms on enrollment in payments for ecosystem services

TABLE 1. Contd.

Reference	Research type	Description
Van Hecken *et al*. (2012)	Original research (Urban Household Surveys)	The viability of local payments for watershed services: empirical evidence from Matiguás, Nicaragua
Tacconi (2012)	Review	Redefining payments for environmental services.
Van der Horst (2011)	Original article	Adoption of payments for ecosystem services: an application of the Hägerstrand model.
Van Noordwijk and Leimona (2010)	Review (Action research)	Principles for fairness and efficiency in enhancing environmental services in Asia: payments, compensation, or co-investment?
Vatn (2010)	Review	An institutional analysis of payments for environmental services.
Kemkes *et al*. (2010)	Review	Determining when payments are an effective policy approach to ecosystem service provision
Muradian *et al*. (2010)	Review	Reconciling theory and practice: an alternative conceptual framework for understanding payments for environmental services
Petheram and Campbell (2010)	Original research	Listening to locals on payments for environmental services

Wunder (2015) provided a comprehensive definition of PES which revealed major elements of the concept as has been popularly cited in many previous research reports. Basically, the following key elements can be deduced from the definition:

1. PES is a voluntary transaction involving well defined ecosystem services.
2. PES involves an ecosystem service (ES) buyer on one hand and an Ecosystem service provider on the other hand where the ES buyer expresses interest to buy the ecosystem service from the ES provider.
3. The ecosystem service provider offers a service on a voluntary basis.
4. Finally, ecosystem service provider must conditionally secure an environmental service provision to win the interest of the ecosystem service provider.

From the perspective of environmental economics, PES offers a market system to facilitate accomplishing a targeted environmental outcome through a modality that internalises economic externalities (McElwee *et al*., 2014; Kaiser *et al.,* 2021). Generally, PES is undertaken with respect to carbon sequestration, water and biodiversity (Carroll and Jenkins, 2008). Though, several PES schemes have been operational since the 2000s, the development in the current years has been more extensive (Sattler and Matzdorf, 2013; Martin-Ortega, and Waylen, 2018). PES programmes hold immense environmental regulating prospects in protecting water quality and ensuring erosion control. Besides, PES programmes supports biodiversity through established mechanisms for natural forest restoration. In a practical guide, Fripp (2014) provided a ten-step guideline to support users in working through the various practical subjects that are of significance in PES programme implementation and hence assess the feasibility of the policy framework.

SWOT ANALYSIS: CASHEW AND TEAK PLANTATION DEVELOPMENT IN GHANA

Coming down to the Ghanaian scenario, a candid SWOT is quite revealing of the prospects for cashew and teak plantation development in Ghana. The main strengths of cashew and teak plantations are that:

(i) Cashew and teak trees are easy or less cumbersome to grow
(ii) Seedlings and production resources are quite available locally
(iii) There are available technologies for production
(iv) Cashew and teak comes with higher Economic benefits
(v) They also come with higher Social benefits and
(vi) Ecological benefits as well are derived from cashew and teak plantations

Reckon that these strengths are internal to the cashew and teak value chain and within easy reach of the farmers acting in the right synergies within a supportive policy environment.

The main weaknesses of cashew and teak plantations are:

(i) Challenges with the land tenure system – land owners are not happy to plant trees on their farm lands
(ii) They ask if they plant trees where will they plant food
(iii) Unclear national policy on the prospects for cashew and teak plantation under PES

The opportunities associated with cashew and teak plantations are:

(i) There is a vast market locally and internationally for cashew and teak products

(ii) There are recently in Ghana a fixed price per kilogramme of cashew nuts
(iii) Cashew and teak trees are well suited to our ecological climatic conditions
(iv) They both have the potential to sequester carbon; and
(v) Reduce atmospheric carbon and other Green House Gases (GHGs)

The threats associated with cashew and teak plantation development vis-à-vis PES are:

(i) Disruptive national events like change of government and tax hikes
(ii) Disruptions on the international geopolitical landscape e.g. war, UN policy
(iii) Political and Economic changes that affect the economic value, demand and supply of commodities

Teak and cashew plantation development in Ghana. The Ghanaian forest sector is one of the key contributors of the nation's gross domestic product (GDP). Thus, the rapid and alarming rate of deforestation and forest degradation in Ghana poses much worry to the government, environmental protection agencies and environmental conservationists (Hansen *et al*, 2009; Oduro *et al*., 2015; Reutemann *et al*., 2016). Generally, environmental or forest or ecosystems degradation issues are not just a concern by specific nations or institutions, rather it is a global issue since degradation is so much linked with global warming and climate change (Muniz and Cruz, 2015; Reutemann *et al.,* 2016). Human livelihood is very much depended on the forest or ecosystems, especially in developing countries where many smallholder farmers depend directly on several ecosystem services (FSD, 2016). Forest degradation arising from the combine defects of exploiting mineral resources, wood for fuel, fodder, and timber has affected many farmlands.

The continuous degradation of forests and consequently farmlands could have serious future repercussions as many lands continue to be stripped off their forests. As a result of these occurrences, various interventions have over the years been implemented such as the integration of farmlands into the nation's forest plantation development programmes. There are also a number of government initiated policies that are measures to encourage the incorporation of forestry into traditional farming systems (Oduro *et al*., 2015). Currently, individuals, and community tree planting projects are being embarked upon across the country under personal sponsorship or sponsorships sourced from the private sector, central government, or NGOs (Nanang, 2012; Oduro *et al*., 2015). It is generally revealed that smallholder tree plantation projects are contributing to improved livelihood through income generation to those actively involved in the diverse activities (Petheram and Campbell, 2010).

Teak (*Tectona grandis*) plantation development in Ghana is considered one of the most important initiatives integrated into the National Forest Plantation Development Programme with support from government to conserve forests (Nar, 2019). In Ghana, teak has become one of the most suitable tree species for establishing plantations aimed at restoring degraded forests as well as to boost the timber industry. The development of teak tree plantation in Ghana can be traced to the early half of 1930s where it began as a smallholder plantation and gradually expanded to large scale plantation project in certain areas within the next three decades (Kalame *et al.,* 2011). Initially, teak plantation in Ghana was found to have contributed to the supply of fire wood for domestic use and thus it was considered as a supplement to that exploited from the forests (Lozano, 2008). A successful implementation of programmes aimed at developing and expanding teak plantation within the country holds immense prospects in sustaining future timber production and restoration of degraded forests. Teak is currently the most dominant tree species in

the Ghanaian forest plantation development projects in terms of total coverage in hectares largely due to its resistance to the effects of wildfires and the increasing international demand (Sools and Wanders, 2011; Wunder, 2015). However, access to lands, land tenure systems and even the readiness of individuals and communities to release lands for forestry projects are a major constraint to the smallholder forest plantations and consequently thwarts efforts geared towards the expansion of forest areas. It has also been previously reported that the smallholder nature of teak plantations is a limitation to fully realising the expected benefits (Insaidoo *et al.,* 2012). In order to assess the forest cover change in the Forest-Savannah transitional zone in Ghana, Owusu and Essandoh-Yeddu (2018) disclosed that the major challenge of teak growers in Ghana includes a lack of funds to support their production. This intuitively calls for alternative approaches in order to facilitate the expansion of teak growing fields. Now on a worldwide scale, the number of projects being implemented under the payment for ecosystem services (PES) has witnessed an increasing trend, with an estimated 550 known programmes currently being implemented (Yang *et al*., 2013; Salzman *et al*., 2018). New effective and efficient government policy interventions are a necessity to enhance ecosystem services and the associated benefits on human livelihood through intensified forestry projects. Integrating the PES into teak and cashew plantation development project in Ghana holds enormous prospects in expanding the plantation fields and providing additional source of incomes to service providers. Beyond the added incomes or economic returns farmers stand to benefit from teak plantations, teak also serves social and ecological objectives.

Cashew (*Anacardium occidentale*) is another economically important fruit tree crop well adapted to many growing environments. However, for a better flowering development and yield, cashew requires a growing condition where the elevation does not exceed 1000 mm with a characteristic optimum temperature and rainfall range of 20 - 34 ^{o}C and 900-1400 mm respectively. Normally, duration of 4-6 months dry period is suitable for flowering and fruiting. Generally, the climatic conditions across almost the entire regions of Ghana are favourable to support cashew cultivation and thus there is a high prospect for cashew production in the country. The cultivation of cashew in Ghana started in the 1960s in areas of two regions, the Greater Accra and Central, from where cultivation was extended to other regions. Today, cashew plantations can be found all over the country. During the early years, about a decade when cashew cultivation began, the industry was constrained by the lack of policy support. However, the cashew industry later rejuvenated with increased interest of many individuals to embark on its cultivation in different locations within the country. The boost followed an economic recovery programme (ERP) which was initiated in the early 1980s by the government of Ghana with the vision to enhance a diversification of the nation's export crops. Following this initiative, cashew cultivation in the country became intensive especially in the 1990s when the Ministry of Food and Agriculture (MOFA) commissioned a study that explored the potential and available domestic and export market opportunities.

The study report revealed among others the tremendous prospects in the cashew industry for export, the potential of generating incomes for rural population and consequently poverty reduction. Since then cashew production in the country has been progressive but undertaken as a smallholder venture. The current development of the industry could be a turning point in achieving the goal of diversifying the nation's export commodity base.

Now cashew cultivation crop has become an integral component of the Ghanaian non-traditional export commodities and thus one of the most profitable cash crops in the

country (Rabany *et al.,* 2015). In their recent study, Danso-Abbeam *et al*. (2021) indicated the role of agricultural loans in promoting a sustainable production of cashew and that provision of loans to cashew farmers will help advance rural farming economy. We also suggest that rather than agricultural loan, the introduction and implementation of the "payment for ecosystem services (PES)" in cashew production could play major roles in increasing production capacity.

Prospects of payment for ecosystem services in cashew and teak plantation development. Payment for ecosystem services with specific reference to cashew and teak plantation entails monetary value and is relevant for rural poverty reduction. A payment for ecosystem services (PES) programme or policy framework is seen as a viable and efficient strategy in protecting ecosystem services through its incorporation into the market system. PES has primarily been established on a regional basis, while worldwide instances are also available (Swallow *et al*., 2009).

Though criticised by some environmentalists (Sattler *et al.,* 2013) as replacing conservational policies with market-based policies, payment for ecosystem services is considered as an incentive-based method to natural resource management. By adhering to PES guiding principles, a PES provider is considered to assume a kind of stewardship responsibility to conserve, improve, or restore ecosystem services for a reward from an ecosystem provider (Muradian, 2013; McElwee *et al*., 2014; Nieratka *et al.*, 2015). "The PES strategy is based on a conceptually simple proposition: pay people or communities to conduct actions that raise levels of desired ecosystem services," (Jack *et al*., 2008). PES increase the monetary value of ES by paying ES providers for their conservation efforts through positive and conditional economic incentives, with the goal of internalising market externalities (Van Noordwijk and Leimona, 2010; McElwee *et al*., 2014; Van Hecken *et al.*, 2015; Kaiser *et al*., 2021). From an environmental economist perspective, PES provides a market-based strategy to attaining environmental goals by allowing economic externalities to be internalised, a topic that has long been recognised and explored in the environmental economics (and broader economics) literature (Turner and Daily, 2007). According to one estimate, environmental service market places is capable of assisting over 600 - 800 million rural poor people by 2030 (Milder *et al*., 2010). Carroll and Jenkins (2008) estimated that widely defined PES-related transactions might reach US$1.1 trillion by 2050, compared with about US$87 billion in 2006.

In Vietnam, PES is noted to be one of the most prominent projects contributing to eradication of poverty, besides biodiversity conservation (McElwee, 2012). Consequently, PES does contribute to poverty reduction among the rural poor through increased household incomes (Muradian *et al*., 2010; Li *et al*., 2011; Börner *et al*., 2017). Evidence of the potential of PES in promoting economic development of people, especially the less privileged rural farmers has also been reported previously (Chen *et al.*, 2018). Now, cashew and teak plantation projects have assumed a status as important economic activities in Ghana. For instance, there is increasing demand for raw cashew nuts in many places across the world, thus indicating a ready market available for its production. This has also given rise to various farmer groups and associations as well as a number of processing plants which source raw nuts from farmers. Currently, cashew is one of the most important plantation species which generates huge incomes in the form of foreign exchange in the country. Similarly, demand for teak tree for wood processing and for electrification projects continue to increase with market readily available. Clearly, the current level of cashew and teak production are not even able to meet the expected demand.

Intensive production and expansion of production area holds immense prospects as an employment and income source for many people in the country. Thus, the adoption of PES in cashew and teak plantation in Ghana will help promote good wellbeing of a vast majority of the Ghanaian population.

Ecological restoration seeks to re-establish ecosystem features such as biodiversity and services that have been degraded or eliminated, typically as a result of human activities (Lu and He 2014; Souza *et al.*, 2016). Restoration activities are progressively being performed in response to the global biodiversity problem, and are backed up by international accords such as the Convention on Biological Diversity (CBD) (Sutherland *et al.*, 2009).

Several studies have shown that PES can conserve and restore ecosystem services at a lower cost than alternative human-built and technical alternatives (Muradian *et al*., 2013; Brownson *et al*., 2019). Ecological restoration has the ability to reverse land degradation, boost biodiversity resilience, and provide vital ecosystem services (Yang *et al*., 2013). PES programme is being widely implemented into natural resource management at all levels, from local to global (Suding, 2011; Martin-Ortega, and Waylen, 2018). An instance is the Sloping Land Conversion Program (SLCP) or the Grain to Green Program (GTGP), which is a PES initiative implemented in China and established at the national level in 1999 to restore natural ecosystems and mitigate adverse off-site effects such as drought, flood, dust storm, sedimentation of reservoirs (Liu, 2010; Chen *et al*., 2018). Following the rapid rate of forest degradation and its consequence on biodiversity, the adoption of the PES programme in teak and cashew plantation in Ghana can serve as a unique opportunity to restore degraded forests.

Environmental conservation can improve landowners' attitudes of environmental preservation and raise participants' knowledge of the connections between ecosystem services and human well-being. Many ecosystem services are viewed as externalities by landowners, providing little motivation for landowners to offer these services (Pagiola *et al*., 2007). It is explicit that human life and survival is very much depended on the numerous services derived from the ecosystem which necessitates the need for its preservation. The expansion of tree plantations implies efforts to preserve the ecosystem and consequently increase the benefits humans derived from the diverse services (Chen *et al*., 2012). Placing a monetary value on these services will serve as a means to consolidate the support of PES participants in preserving such services (Pagiola *et al*., 2007; Engel *et al*., 2008).

Key on-site environmental preservation benefits of PES programmes include decreased reliance on pesticides, water savings, higher soil fertility, and shade, all of which are initially neglected by landowners but may be swiftly recognised after a program is established on their property (SFA, 2014) under the PES system. Though sometimes criticised (Muradian *et al*., 2010; Ponette-González *et al*., 2014), PES has been considered as one of the outstanding programmes to promote environmental conservation (Schomers and Matzdorf, 2013).

For promoting climate change adaptation, ecosystems are critical to human well-being due to the myriad advantages they provide. For example, ecosystem provisioning services are critical due to their consequences for food security and livelihoods, which are inextricably related to disasters and climate change. The natural infrastructure of an ecosystem is made up of the structures and functions of the ecosystem that work together to offer the services and benefits to humans (Petheram and Campbell, 2010; Uy and Shaw, 2012). The multiple effects of climate change on global biodiversity are a concern to environmental conservationists (Hoffman *et al*., 2019). Due to their potential to manage climate and natural hazards, ecosystems constitute significant natural capital. By continuing to offer

protective functions and other ecosystem services endangered by climate change, well-managed ecosystems can aid in disaster risk reduction and climate change adaptation (Uy and Shaw, 2012). Ecosystems' regulatory functions have a specific direct impact on climate and natural disasters. These regulatory and protecting roles include the regulation, storage, and retention of water, disturbance regulation, erosion management; and sediment retention (Sudmeier-Rieux *et al.,* 2006).

Ecosystems influence climate control in different ways such as extreme conditions of warming and cooling, water redistribution/ recycling and variation in regional rainfall patterns. Ecosystems, both natural and managed, have a significant impact on climate and air quality as sources and sinks of pollutants, reactive gases, greenhouse gases, and aerosols, as well as on heat and water fluxes owing to their physical features. Anderson-Texeira *et al.* (2012) demonstrate that natural ecosystems have a greater value for climate control than agro-ecosystems due to the differences in biogeochemical services, confirming the critical relevance of tropical forest protection. Therefore, the introduction of PES system in cashew and teak plantation programmes will be a valuable way to speed the rate of mitigating impacts of climate change.

Tree planting is a promising agricultural venture with the ability to mitigate and adapt to climate change (Lin, 2007). Apart from carbon sequestration, shade trees enhance local climatic conditions and modulate microclimate and soil moisture variability (Lin, 2007). Along with regulatory functions, the associated shade tree species supply a variety of direct ecosystem services (ESs), such as food, fodder, and firewood (Muradian *et al*., 2010; Naeem *et al*., 2015; Sunderland, 2017). Tree crops in agricultural landscapes can provide more suitable environments for soil biodiversity, encouraging 'hot spots' of biological activity responsible for a variety of ecological processes critical to soil health (Pauli *et al*., 2010; Ushio *et al*., 2010). Additionally, although not always, increased tree cover decreases insect pressures and increases pollination services (Ricketts *et al*., 2004; Pumario *et al.,* 2015).

CONCLUSION

From the foregoing, the key findings are that payment for ecosystem services (PES) has received worldwide recognition for its prospects in biodiversity conservation, and its contribution to livelihood improvement through poverty reduction. Research has found that cashew and teak trees are among the foremost tree species that has significant prospects for payment for ecosystems vis-à-vis their contribution to reforestation and reclamation of degraded forests and ecosystems.

This study identified a research gap and sought to explore the possibility of adopting PES for ecosystem conservation in Ghana. Extensive research was required with regards to the opportunities available in implementing PES in Ghana, identifying target and priority areas where PES is likely to be more applicable, identifying potential ecosystem service providers and actors as well as a model of PES that will suit the Ghanaian conservation management system. In this current review, we are of the view that the adoption and implementation of PES holds immense potential in the development of cashew and teak plantation projects in Ghana. Further research was needed from diverse disciplines to evaluate the economic, biological and social implications of adopting PES in tree and plantation systems and consequently effects on agricultural systems.

REFERENCES

Anderson-Teixeira, K.J., Snyder, P.K., Twine, T.E, Cuadra, S.V., Costa, M.H. and DeLucia, E.H. 2012. Climate-regulation services of natural and agricultural ecoregions of the Americas. *Nature Climate*

Change 2(3):177-181. http://dx.doi.org/10.1038/nclimate1346

Angelsen, A. 2010. Policies for reduced deforestation and their impact on agricultural production. *Proceedings of the National Academy of Sciences* 107(46): 19639-19644. http://dx.doi.org/10.1073/pnas.0912014107

Brownson, K., Guinessey, E., Carranza, M., Esquivel, M., Hesselbach, H., Ramirez, L. M. and Villa, L. 2019. Community based payments for ecosystem services (CB-PES): Implications of community involvement for program outcomes. *Ecosystem Services* 39:1-14. http://dx.doi.org/10.1016/j.ecoser.2019.100974.

Carroll, N. and Jenkins, M. 2008. The matrix: Mapping ecosystem service markets. Forest trends and ecosystem marketplace, Washington, DC, USA. http://www.ecosystemmarketplace.com/pages/dynamic/article. page. php.

Chen, S. and Kagatsume, M. 2018. Impacts of environmental conservation programs on regional economic structural change in Guizhou, China, from 2002 to 2012: An input–output analysis. *Journal of Economic Structures* 7(1):1-18. http://dx.doi.org/10.1186/s40008-018-0120-4.

Chen, X., Lupi, F., An, L., Sheely, R., Viña, A. and Liu, J. 2012. Agent-based modeling of the effects of social norms on enrollment in payments for ecosystem services. *Ecological Modeling* 229:16-24. http://dx.doi.org/10.1016/j.ecolmodel.2011.06.007.

Cook, D.C., Kristensen, N.P. and Liu, S. 2016. Coordinated service provision in payment for ecosystem service schemes through adaptive governance. *Ecosystem Services* 19:103-108. http://dx.doi.org/10.1016/j.ecoser.2016.01.008.

Christie, M., Fazey, I., Cooper, R., Hyde, T., and Kenter, J.O. 2012. An evaluation of monetary and non-monetary techniques for assessing the importance of biodiversity and ecosystem services to people in countries with developing economies. *Ecological Economics* 83:67-78. http://dx.doi.org/10.1016/j.ecoser.2016.01.008.

Danso-Abbeam, G., Fosu, S. and Ogundeji, A.A. 2021. Technical and resource-use efficiencies of cashew production in Ghana: Implications on achieving sustainable development goals. *Scientific African* 14:1-11. http://dx.doi.org/10.1016/j.sciaf.2021.e01003.

DeFries, R.S., Foley, J.A. and Asner, G.P. 2004. Land-use choices: Balancing human needs and ecosystem function. *Frontiers in Ecology and Environment* 2(5):249-257.

Derkyi, M., Adiku, S.G., Nelson, V., Delali Dovie, B., Codjoe, S. and Awuah, E. 2018. Smallholder farmers' perception of climatic and socio-economic factors influencing livelihoods in the transition zone of Ghana. AAS Open Research. Research. ISSN 2515-9321 (Online). doi: https://doi.org/10.12688/aasopenres.12839.1

Díaz, S., Quétier, F., Cáceres, D.M., Trainor, S.F., Pérez-Harguindeguy, N. and Bret-Harte, M.S. 2011. Linking functional diversity and social actor strategies in a framework for interdisciplinary analysis of nature's benefits to society. *Proceedings of the National Academy of Sciences of the United States of America* 108(3):895-902. https://doi.org/10.1073/pnas.1017993108.

Duraiappah, A.K. and Bhardwaj, A. 2007. Measuring policy coherence among the MEAs and MDGs. Winnipeg: International Institute for Sustainable Development. 53pp. https://www.iisd.org/system/files/publications/measuring_policy.pdf.

Engel, S. 2015. The devil in the detail: A practical guide on designing payments for environmental services. *International Review of Environmental and Resource Economics* 9:131-177. http://dx.doi.org/10.12688/aasopenres.12839.1.

Engel, S. and Muller, A. 2016. Payments for environmental services to promote "climate smart agriculture"? Potential and

challenges. *Agricultural Economics* 47(S1):173-184. http://dx.doi.org/10.2139/ssrn.2712385.

Engel, S., Pagiola, S. and Wunder, S. 2008. Designing payments for environmental services in theory and practice: An overview of the issues. *Ecological Economics* 65(4):663-674. http://dx.doi.org/10.1016/j.ecolecon.2008.03.011.

Ezzine-De-Blas, D., Dutilly, C., Lara-Pulido, J.A., Le Velly, G. and Guevara-Sanginés, A. 2016. Payments for environmental services in a policymix: spatial and temporal articulation in Mexico. *PLoS ONE* 11(4): 1-15. http://dx.doi.org/10.1371/journal.pone.0152514.

FAO (Food and Agriculture Organization of the United Nations). 2011. Save and grow: A Policymaker's Guide to Sustainable Intensification of Smallholder Crop Production. Rome, Italy: Food and Agriculture Organization of the United Nations.

Fripp, E. 2014. Payments for Ecosystem Services (PES): A practical guide to assessing the feasibility of PES projects. Bogor, Indonesia: CIFOR.

Forest Services Division (FSD). 2016. National forest plantation development programme, 2015 annual report. Accra: Forestry Commission of Ghana. http://dx.doi.org/10.17528/cifor/005260.

Grima, N., Singh, S.J., Smetschka, B. and Ringhofer, L. 2016. Payment for ecosystem services (PES) in Latin America: analysing the performance of 40 case studies. *Ecosystem Services* 17:24-32.

Guuroh, R.T., Foli, E.G., Addo-Danso, S.D., Stanturf, J.A., Kleine, M. and Burns J. 2021. Restoration of degraded forest reserves in Ghana. *Reforesta* 12:35-55. http://dx.doi.org/10.1016/j.ecoser.2015.11.010.

Haines-Young, R. and Potschin, M. 2010. The links between biodiversity, ecosystem services and human well-being. In: Raffaelli, C.L.J. and Frid, D.G. (Eds.). Ecosystem ecology: A new synthesis. Cambridge (United Kingdom): Cambridge University Press. pp. 110-139. http://dx.doi.org/10.1017/cbo 9780511750458.007.

Hayes, T., Murtinho, F. and Wolff, H. 2017. The impact of payments for environmental services on communal lands: An analysis of the factors driving household land-use behavior in Ecuador. World Development 93:427-446. http://dx.doi.org/10.1016/j.worlddev.2017.01.003.

Hoffmann, A.A., Rymer, P.D., Byrne, M., Ruthrof, K.X., Whinam, J. and McGeoch, M. 2018. Impacts of recent climate change on terrestrial flora and fauna: Some emerging Australian examples. Austral Ecology 44(1):3-27. http://dx.doi.org/10.1111/aec.12674.

Huber-Stearns, H.R., Goldstein, J.H. and Duke, E.A. 2013. Intermediary roles and payments for ecosystem services: A typology and program feasibility application in Panama. *Ecosystem Services* 6:104-116. http://dx.doi.org/10.1016/j.ecoser.2013.09.006.

Iniguez-Gallardo, V, Halasa, Z and Briceño, J. 2018. People's perceptions of ecosystem services provided by tropical dry forests: A comparative case study in Southern Ecuador. Tropical Forests - New Edition pp. 1-21. http://dx.doi.org/10.5772/intechopen.75081.

Insaidoo, T.F.G., Ros-Tonen, M.A.F. and Acheampong, E. 2012. On-farm tree planting in Ghana's high forest zone: The need to consider carbon payments. Governing the Provision of Ecosystem Services. Springer Netherlands 3:437-463. http://dx.doi.org/10.1007/978-94-007-5176-7_22.

Kaiser, J., Haase, D. and Krueger, T. 2021. Payments for ecosystem services: A review of definitions, the role of spatial scales, and critique. *Ecology and Society* 26(2):1-25.

http://dx.doi.org/10.5751/es-12307-260212.

Kalame, F.B., Aidoo, R., Nkem, J., Ajayie, O.C., Kanninen, M,, Luukkanen, O. and Idinoba, M. 2011. Modified taungya system in Ghana: A win–win practice for forestry and adaptation to climate change? *Environmental Science and Policy* 14(5): 519 - 530. http://dx.doi.org/10.1016/j.envsci.2011.03.011.

Kemkes, R.J., Farley, J. and Koliba, C.J. 2010. Determining when payments are an effective policy approach to ecosystem service provision. *Ecological Economics* 69(11):2069-2074. http://dx.doi.org/10.1016/j.ecolecon.2009.11.032.

Kosoy, N., Martinez-Tuna, M., Muradian, R. and Martinez-Alier, J. 2007. Payments for environmental services in watersheds: Insights from a comparative study of three cases in Central America. *Ecological Economics* 61(2-3):446-455. http://dx.doi.org/10.1016/j.ecolecon.2006.03.016.

Kremen, C., Williams, N.M., Aizen, M.A., Gemmill-Herren, B., LeBuhn, G. and Minckley, R. 2007. Pollination and other ecosystem services produced by mobile organisms: A conceptual framework for the effects of land-use change. Ecology Letters, 10(4), 299–314. http://dx.doi.org/10.1111/j.1461-0248.2007.01018.x.

Li, J., Feldman, M.W., Li, S. and Daily, G.C. 2011. Rural household income and inequality under the sloping land conversion program in Western China. *Proceedings of the National Academy of Sciences of the United States of America* 108(19):7721–7726. http://dx.doi.org/10.1073/pnas.1101018108.

Lima, L.S., Krüger, T. and García-Marquez, J. 2017. Uncertainties in demonstrating environmental benefits of payments for ecosystem services. *Ecosystem Services* 27:139-149. http://dx.doi.org/10.1016/j.ecoser.2017.09.005.

Lin, B.B. 2007. Agroforestry management as an adaptive strategy against potential microclimate extremes in coffee agriculture. *Agricultural and Forest Meteorology* 144(1-2):85-94. http://dx.doi.org/10.1016/j.agrformet.2006.12.009.

Lozano, R. 2008. Envisioning sustainability three-dimensionally. *Journal of Cleaner Production* 16(17):1838-1846. http://dx.doi.org/10.1016/j.jclepro.2008.02.008.

Millennium Ecosystem Assessment (MA). 2005. Ecosystems and Human Well-Being; Island Press: Washington, DC,, USA. pp. 25-36.

Mace, G.M., Norris, K. and Fitter, A.H. 2012. Biodiversity and ecosystem services: A multilayered relationship. *Trends in Ecology and Evolution* 27(1):19-26. http://dx.doi.org/10.1016/j.tree.2011.08.006.

Matzdorf, B., Sattler, C. and Engel, S. 2013. Institutional frameworks and governance structures of PES schemes. *Forest Policy and Economics* 37:57-64. http://dx.doi.org/10.1016/j.forpol.2013.10.002.

Martin-Ortega, J. and Waylen, K.A. 2018. PES what a mess? An analysis of the position of environmental professionals in the conceptual debate on payments for ecosystem services. *Ecological Economics* 154:218-237. http://dx.doi.org/10.1016/j.ecolecon.2018.08.001.

Milder, J.C., Scherr, S.J. and Bracer, C. 2010. Trends and future potential of payment for ecosystem services to alleviate rural poverty in developing countries. *Ecology and Society* 15(2):1-19. http://dx.doi.org/10.5751/es-03098-150204.

MOFA-SRID. 2010. Agriculture in Ghana. Facts and figures (2010).

Muniz, R. and Cruz, M.J. 2015. Making nature valuable, not profitable: Are payments for ecosystem services suitable for degrowth? *Sustainability* 7(8):10895-10921. http://dx.doi.org/10.3390/su70810895.

Muradian, R., Corbera, E., Pascual, U., Kosoy, N. and May, P.H. 2010. Reconciling theory and practice: An alternative conceptual framework for understanding payments for environmental services. *Ecological Economics* 69(6):1202-1208. http://dx.doi.org/10.1016/j.ecolecon.2009.11.006.

Muradian, R. 2013. Payments for ecosystem services as incentives for collective action. *Society & Natural Resources* 26(10):1155-1169. http://dx.doi.org/10.1080/08941920.2013.820816.

Muradian, R.M., Arsel, L., Pellegrini, F., Adaman, B., Aguilar, B. and Agarwal, E. 2013. Payments for ecosystem services and the fatal attraction of win-win solutions. *Conservation Letters* 6(4):274-279. http://dx.doi.org/10.1111/j.1755-263x.2012.00309.x.

Naeem, S., Ingram, J.C., Varga, A., Agardy, T., Barten, P. and Bennett, G. 2015. Get the science right when paying for nature's services. *Science* 347(6227):1206-1207.

Narloch, U., Drucker, A.G. and Pascual, U. 2017. What role for cooperation in conservation tenders? Paying farmer groups in the High Andes. *Land Use Policy* 63:659-671. http://dx.doi.org/10.1016/j.landusepol.2015.09.017.

Nieratka, L.R., Bray, D.B. and Mozumder, P. 2015. Can payments for environmental services strengthen social capital, encourage distributional equity, and reduce poverty? *Conservation and Society* 13(4):345-355. http://dx.doi.org/10.4103/0972-4923.179880.

Oduro, K.A., Mohren, G.M.J., Peña-Claros, M., Kyereh, B. and Arts, B. 2015. Tracing forest resource development in Ghana through forest transition pathways. *Land Use Policy* 48:63-72. http://dx.doi.org/10.1016/j.landusepol.2015.05.020.

Pagiola, S., Ramírez, E., Gobbi, J., de Haan, C., Ibrahim, M., Murgueitio, E. and Ruíz, J.P. 2007. Paying for the environmental services of silvopastoral practices in Nicaragua. *Ecological Economics* 64(2):374-385. http://dx.doi.org/10.1016/j.ecolecon.2007.04.014.

Pascual, U., Balvanera, P., Díaz, G., György, P., Roth, E. and Stenseke, M. 2017. Valuing nature's contributions to people: the IPBES approach. *Current Opinion in Environmental Sustainability* 26-27:7-16.

Pauli, N., Oberthür, T., Barrios, E. and Conacher, A.J. 2010. Fine-scale spatial and temporal variation in earthworm surface casting activity in agroforestry fields, western Honduras. *Pedobiologia* 53(2):127-139. http://dx.doi.org/10.1016/j.pedobi.2009.08.001.

Petheram, L. and Campbell, B.M. 2010. Listening to locals on payments for environmental services. *Journal of Environmental Management* 91(2):1139-1149. http://dx.doi.org/10.1016/j.jenvman.2010.01.002.

Pirard, R. 2012. Payments for Environmental Services (PES) in the public policy landscape: "Mandatory" spices in the Indonesian recipe. *Forest Policy and Economics* 18:23-29. http://dx.doi.org/10.1016/j.forpol.2011.09.002.

Ponette-González, A.G., Brauman, K.A., Marín-Spiotta, E., Farley, K.A., Weathers K.C. and Young, K.R. 2014. Managing water services in tropical regions: From land cover proxies to hydrologic fluxes. *Springer Science and Business Media LLC* 44(5):367-75. http://dx.doi.org/10.1007/s13280-014-0578-8.

Power, A.G. 2010. Ecosystem services and agriculture: Tradeoffs and synergies. *Philosophical Transactions of the Royal Society B: Biological Sciences* 365(1554):2959-2971. http://dx.doi.org/10.1098/rstb.2010.0143.

Quijas, S., Schmid, B. and Balvanera P. 2010. Plant diversity enhances provision of ecosystem services: A new synthesis. *Basic and Applied Ecology* 11(7):582-593. http://dx.doi.org/10.1016/j.baae.2010.06.009.

Quijas, S. and Balvanera, P. 2013. Biodiversity and Ecosystem Services. Encyclopedia of Biodiversity 341–356. http://dx.doi.org/10.1017/cbo9781107338913.007.

Rabany, C., Rullier, N. and Ricau, P. 2015. The African cashew sector in 2015. General trends and country profiles.

Reed, M.S., Allen, K., Attlee, A., Dougill, A.J., Evans, K.L., Kenter, J.O., Hoy, J., McNab, D., Stead, S.M., Twyman, C., Scott, A.S., Smyth, M.A., Stringer, L.C. and Whittingham, M.J. 2017. A place-based approach to payments for ecosystem services. *Global Environmental Change* 43:92-106.

Reed, M.S., Moxey, A., Prager, K., Hanley, N., Skates, J., Bonn, A., Evans, C.D., Glenk, K. and Thomson, K. 2014. Improving the link between payments and the provision of ecosystem services in agri-environment schemes. *Ecosystem Services* 9:44-53. http://dx.doi.org/10.1016/j.ecoser.2014.06.008.

Reutemann, T., Engel, S. and Pareja, E. 2016. How (not) to pay-field experimental evidence on the design of REDD+ payments. *Ecological Economics* 129: 220-229.

Ricketts, T.H., Daily, G.C., Ehrlich, P.R. and Michener, C.D. 2004. Economic value of tropical forest to coffee production. *Proceedings of the National Academy of Sciences* 101:12579-12582. http://dx.doi.org/10.1073/pnas.0405147101.

Salzman, J., Bennett, G., Carroll, N., Goldstein, A. and Jenkins, M. 2018. The global status and trends of payments for ecosystem services. *Nature Sustainability* 1(3):136-144. http://dx.doi.org/10.1038/s41893-018-0033-0.

Sattler, C. and Matzdorf, B. 2013. PES in a nutshell: from definitions and origins to PES in practice - approaches, design process and innovative aspects. *Ecosystem Services* 6:2-11. http://dx.doi.org/10.1016/j.ecoser.2013.09.009.

Sattler, C., Trampnau, S., Schomers, S., Meyer, C. and Matzdorf, B. 2013. Multi-classification of payments for ecosystem services: How do classification characteristics relate to overall PES success? *Ecosystem Services* 6:31-45. http://dx.doi.org/10.1016/j.ecoser.2013.09.007.

Scheffers, B.R., De Meester, L., Bridge, T.C.L., Hoffmann, A.A., Pandolfi, J.M. and Corlett, R.T. 2016. The broad footprint of climate change from genes to biomes to people. *Science* 354(6313):1-14. http://dx.doi.org/10.1126/science.aaf7671.

Schomers, S. and Matzdorf, B. 2013. Payments for ecosystem services: a review and comparison of developing and industrialized countries. *Ecosystem Services* 6:16-30. http://dx.doi.org/10.1016/j.ecoser.2013.01.002.

Schröter, B., Matzdorf, B., Hackenberg, I. and Hauck, J. 2018. More than just linking the nodes: civil society actors as intermediaries in the design and implementation of payments for ecosystem services - The case of a blue carbon project in Costa Rica. *Local Environment* 23(6):635-651. http://dx.doi.org/10.1080/13549839.2018.1460808.

SFA. 2014. Analysis Report of 2014 National Forestry Statistical Report. Beijing: State Forestry Administration.

Sorice, M.G., Donlan, C.J., Boyle, K.J., Xu, W. and Gelcich, S. 2018. Scaling participation in payments for ecosystem services programs. *PLoS ONE* 13(3): e0192211. http://dx.doi.org/10.1371/journal.pone.0192211.

Souza, C.A., Gallardo, A.L.C.F., Silva, É.D.D., Mello, Y.C.D., Righi, C.A. and Solera, M.L. 2016. Environmental services associated with the reclamation of areas degraded by mining: Potential for payments for environmental services. Ambiente and Sociedade. *FapUNIFESP (SciELO)* 19(2): 137-68. http://dx.doi.org/10.1590/1809-4422asoc129835v1922016.

Study of Critical Environmental Problems (SCEP). 1970. Man's impact on the global environment; MIT Press: Cambridge, MA, USA. 319pp.

Suding, K.N. 2011. Toward an era of restoration in ecology: Successes, failures, and opportunities ahead. *Annual Review of Ecology, Evolution, and Systematics* 42(1): 465–487. http://dx.doi.org/10.1146/annurev-ecolsys-102710-145115.

Sudmeier-Rieux, K., Masundire, H., Rizvi, A. and Rietbergen, S. (Eds.). 2006. Ecosystems, livelihoods and disasters: An integrated approach to disaster risk management pp. 1-41. http://dx.doi.org/10.2305/iucn.ch.2006.cem.4.en.

Swallow, B.M., Kallesoe, M.F., Iftikhar, U.A., van Noordwijk, M., Bracer, C. and Scherr, S.J. 2009. Compensation and rewards for environmental services in the developing world: Framing pan-tropical analysis and comparison. *Ecology and Society* 14(2). http:// dx.doi.org/10.5716/wp14963.pdf.

Swinton, S.M., Lupi, F., Robertson, G.P. and Hamilton, S.K. 2007. Ecosystem services and agriculture: Cultivating agricultural ecosystems for diverse benefits. *Ecological Economics* 64(2):245-252. http://dx.doi.org/10.1016/j.ecolecon.2007.09.020

Tacconi, L. 2012. Redefining payments for environmental services. *Ecological Economics* 73:29-36. http://dx.doi.org/10.1016/j.ecolecon.2011.09.028.

TEEB. 2010. The Economics of Ecosystems and Biodiversity, Ecological and Economic Foundations. Routledge, Abingdon, UK. 410pp. http://dx.doi.org/10.4324/9781849775489

Thompson, B.S. 2018. Institutional challenges for corporate participation in payments for ecosystem services (PES): Insights from Southeast Asia. *Sustainability Science* 13: 919-935. http://dx.doi.org/10.1007/s11625-018-0569-y

Tilman, D., Reich, P.B. and Knops, J.M.H. 2006. Biodiversity and ecosystem stability in a decade-long grassland experiment. *Nature* 441:629-632. http://dx.doi.org/10.1038/nature04742

Turner, R.K. and Daily, G.C. 2007. The Ecosystem Services Framework and Natural Capital Conservation. *Environmental and Resource Economics* 39:25-35. http://dx.doi.org/10.1007/s10640-007-9176-6

Ushio, M., Kitayama, K. and Balser, T.C. 2010. Tree species effects on soil enzyme activities through effects on soil physicochemical and microbial properties in a tropical montane forest on Mt. Kinabalu, Borneo. Pedobiologia 53, 227–233. http://dx.doi.org/10.1016/j.pedobi.2009.12.003.

Uy, N. and Shaw, R. 2012. The role of ecosystems in climate change adaptation and disaster risk reduction. *Community, Environment and Disaster Risk Management*. pp. 41-59.

Van der Horst, D. 2011. Adoption of payments for ecosystem services: an application of the Hägerstrand model. *Applied Geography* 31(2):668-676. http://dx.doi.org/10.1016/j.apgeog.2010.12.001.

Van Hecken, G., Bastiaensen, J. and Huybrechs, F. 2015. What's in a name? Epistemic perspectives and payments for ecosystem services policies in Nicaragua. *Geoforum* 63:55-66. http://dx.doi.org/10.1016/j.geoforum.2015.05.020

Van Hecken, G.. Bastiaensen, J. and Vásquez, W.F. 2012. The viability of local payments for watershed services: Empirical evidence from Matiguás, Nicaragua. *Ecological Economics* 74:169-176.

Van Noordwijk, M. and Leimona, B. 2010. Principles for fairness and efficiency in enhancing environmental services in Asia: payments, compensation, or co-investment? Ecology and Society 15, 17. http://dx.doi.org/10.5751/es-03664-150417

Van denPutte, A., Govers, G., Diels, J., Gillijns, K. and Demuzere, M. 2010. Assessing the effect of soil tillage on crop growth: A meta-regression analysis on European crop yields

under conservation agriculture. *European Journal of Agronomy* 33:231-241. http://dx.doi.org/10.1016/j.eja.2010.05.008.

Van der Plas, F. 2019. Biodiversity and ecosystem functioning in naturally assembled communities *Biological Reviews* 94:1220-1245.

Vatn, A. 2010. An institutional analysis of payments for environmental services. *Ecological Economics* 69:1245-1252. http://dx.doi.org/10.1016/j.ecolecon.2009.11.018

Wu, Y. and Qiaoling, L. 2018. Integrated evaluation of payments for ecosystem services programs in China: a systematic review, *Ecosystem Health and Sustainability* 4:73-84. http://dx.doi.org/10.1080/20964129. 2018.1459867.

Wunder, S. 2005. Payments for environmental services: Some nuts and bolts. CIFOR Occasional Paper, 42, 3-4. http://dx.doi.org/10.17528/cifor/001760.

Wunder, S. 2013. When payments for environmental services will work for conservation. *Conservation Letters* 6:230-237. http://dx.doi.org/10.1111/conl.12034.

Wunder, S. 2015. Revisiting the concept of payments for environmental services. *Ecological Economics* 117:234-243. http://dx.doi.org/10.1016/j.ecolecon.2014.08.016

Yan, E., Lin, H., Dang, Y. and Xia, C. 2014. "The spatiotemporal changes of vegetation coverin Beijing-Tianjin Sandstorm Source Control Region during 20002012. *Acta Ecologica Sinica* 34:5007-5020. http://dx.doi.org/10.5846/stxb201305251179.

Yang, W., Liu, W., Viña, A., Luo, J., He, G., Ouyang, Z. and Liu, J. 2013. Performance and prospects on payments for ecosystem services programs: Evidence from China. *Journal of Environmental Management* 127:86-95. http://dx.doi.org/10.1016/j.jenvman.2013.04.019.

Zhang, W., Ricketts, T.H., Kremen, C., Carney, K. and Swinton, S.M. 2007. Ecosystem services and dis-services to agriculture. *Ecological Economics* 64: 253-260. http://dx.doi.org/10.1016/j.ecolecon.2007.02.024.