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Research paper

Using the ecosystem service approach to determine whether jatropha projects were located in marginal lands in Ghana: Implications for site selection

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A B S T R A C T

The concept of marginal land is often used to justify land availability and inform land allocation for biofuel projects. However, marginal lands can provide other valuable ecosystem services. Using interviews with multiple stakeholders and fieldwork in three collapsed biofuel projects in Ghana, this paper shares perspectives on how the ecosystem service approach (ESA) can offer a better basis for selecting land for biofuel projects. Expert interviews with key stakeholders (e.g. Lands Commission) in biofuel value chains in Ghana highlight the lack of consensus of what constitutes marginal land, with two dominant interpretations coming up; (i) land unsuitable for food production and (ii) land unsuitable for cost-effective agricultural production. Both interpretations however do not reflect the ecosystem services lands provide, as well as the significant cultural values attached to them. Our empirical work shows that many ecosystem services are obtained from the supposedly marginal lands that are neglected from both interpretations, as well as the standard project planning and Environmental Impact Assessment (EIA) processes. We make the case that when compared to the current marginal land narrative, the ESA offers a better lens for understanding local land uses, in managing emerging tradeoffs and providing information for locating biofuel projects. Our findings suggest that expanding the scope of EIAs by integrating elements of the ESA can go a long way towards informing site selection for biofuel investments.

1. Introduction

Numerous studies have raised concerns about the potential threat that biofuel expansion can pose to food production [1–6]. To this end, there has been a heated discussion whether it is ethically acceptable to promote commercial biofuel feedstock production, especially in the food insecure developing countries of Sub-Sahara Africa (SSA) [7]. These discussions have often been framed as the "fuel vs. food" debate [8,9].

The notion that biofuel feedstock production on marginal lands could circumvent the "food vs. fuel" dilemma has attracted an increasing attention in the academic literature [7,10–12]. Despite its long history as a term, marginal land became very popular in the biofuel literature only after the prominence of the "food vs. fuel" debate [11]. Early use of the concept of marginal land date back to Ricardo (1817) and the law of rent, which states that the marginal cost of land rent is a good reason for shifting capital and labour between high-quality land and 'marginal land' [13]. Peterson and Galbraith (1932) added some dynamism in the concept by introducing three terms: physically marginal (i.e. marginality based on location and environmental factors), productively marginal (i.e. marginality related to food suitability), and economically marginal (i.e. marginality related to cost-effectiveness of agricultural production) [14]. The cost-effective definition of marginal land was largely used in the economic theory of land and rent before the emergence of the biofuel debate [11]. The food suitability aspect of marginal land was largely promoted within the biofuel discourse as discussed below [15].

While a stringent definition of marginal land would preclude the production of biofuel feedstock in such areas, this is not the case in the biofuel literature. In reality several studies around the world (including SSA) have identified marginal lands as areas fit for sustainable biofuel feedstock production as a means of avoiding the food-fuel competition [15–17] (see below).

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Abbreviations

CSO	Civil Society Organisation
ESA	Ecosystem Service Approach
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
FGD	Focus Group Discussion
FDI	Foreign Direct Investment
MoFA	Ministry of Food and Agriculture
NTFP	Non-Timber Forest Product
SSA	Sub-Sahara Africa
TCPD	Town and Country Planning Department

There are however, many contested points regarding the current use of the term for biofuel feedstock production. These include: (i) what constitutes marginal land, (ii) where such lands are located, (iii) how much marginal land is available for biofuel feedstock production, and (iv) what are the differences between marginal land and abandoned and/or degraded land. In recent years discussions about the above have emerged both in academic [15,18,19] and policy/practice [16] domains.

Regarding the first point, two major definitions of marginal land can be found in the academic literature as they relate to biofuels. The first defines marginal land in relation to land suitability for food production, and particularly for growing food crops [16,17]. Proximate factors such as climate, erosion, soil quality, and other environmental risks are usually used to determine land suitability for food production [15–17]. However, studies about crop yields on marginal lands have generally generated mixed results, increasing the skepticism for using this criterion to determine what constitutes marginal land [15,20,21]. The second definition relates marginal land to the limited possibilities for cost-effective agricultural production, thus adopting a more economic viewpoint discussed above [11,22]. Whereas the first definition has normative undertones, the latter conveys practical considerations as to what constitutes a marginal land [11].

Regarding the second and third point, a recent meta-analysis indicates that marginal land accounts for 9 910 000 km^2 globally [23]. In SSA, the extent of marginal lands has been estimated at 1 320 000 km^2 [23,24]. While these studies use proxies [19] or provide contradictory results in terms of production, land availability, and the ability to target these areas [15,21,25], they nonetheless have offered a foundation to propagate the idea that marginal lands are abundant in SSA and can be used for biofuel production.

Across SSA, the notion that such marginal lands fit for biofuel production do exist has been used to build national support and attract foreign direct investments (FDIs) [7,15]. However, studies on the prospects and challenges of using marginal lands for biofuel development in SSA can be contentious [15] and offer limited advice for informed policy-making [7].

It has been argued that the current framing, quantification, and classification of marginal lands are not actually helpful in SSA contexts as many local uses of the land are ignored [26]. Indeed, classifying marginal lands as outlined above can overlook many of the other uses of land, including the benefits derived from ecosystems (i.e. ecosystem services). In other words, the fact that land is unsuitable or uneconomic for food production does not necessarily mean that it does not cater for multiple other human needs by providing ecosystem services that contribute to human well-being [27–29].

Research in SSA, has suggested that there are indeed many ecosystem service impacts related to biofuel-driven large-scale land conversion [1,15,30,31]. Understanding the ecosystem service trade-offs during the life-cycle of biofuel investments (and particularly for the feedstock production stage) can have important ramifications for biofuel project planning including the selection of site, feedstock and agricultural, management practices.

From this starting point, the aim of the paper is to identify some of the misconceptions that arise when using the marginal land narrative as a basis to choose the location of biofuel feedstock production, as well as how the ecosystem services approach (ESA) can offer a complementary lens for biofuel project planning. We use examples from jatropha production in Ghana that offers an ideal context for this study as it experienced some of the most significant biofuel expansion in SSA [32] on supposedly marginal land, which was followed by a widespread collapse of the sector [33].

After outlining the methodology of this study (Section 2), we identify the critical lack of consensus between key stakeholders in Ghana on what constitutes marginal land appropriate for biofuel feedstock production (Section 3.1). Then we use the ESA approach to report the actual uses/benefits derived from supposedly marginal lands in three jatropha projects in Ghana before the land conversion to jatropha monocultures, and after project collapse (Section 3.2–3.3). Following this, we then identify the important mismatches between these uses/benefits and the actual impacts considered in the official EIA reports (Section 3.4). Finally, we put these findings into perspective and address some fundamental issues related to the use of the ESA for biofuel project planning (Section 4).

2. Methodology

2.1. Data collection and analysis

For the purpose of this study we employ the definition and classification of ecosystem services adopted by the major ecosystem services initiatives of the last decade [28,28,29] as applied in ecosystem services settings [56]. Based on these, ecosystem services are the benefits that humans derive directly and indirectly from nature, including:

- Provisioning services: e.g. food, fuelwood, clean water, medicinal plants
- Regulating services: e.g. climate regulation, water purification, erosion regulation
- Cultural services: e.g. recreation, aesthetic and religious values
- Supporting services: e.g. habitat provision, soil formation, nutrient cycles

Primary data was collected during two rounds of fieldwork (Table 1). During the first fieldwork (September 2015) we undertook (a) expert interviews to interpret the diverse meaning of the term marginal land among key stakeholders in Ghana, and (b) household surveys around three jatropha projects to understand changes in provisioning ecosystem services following landscape conversion (Table 1) (see Section 2.2). During the second fieldwork (February–March 2016) we undertook (a) participatory mapping to understand better the landscape modifications, and (b) focus group discussions (FGDs) to understand changes in regulating and cultural ecosystem services and substantiate the changes in provisioning ecosystem services identified during the household survey.

The expert interviews were conducted with key representatives of major stakeholders in the land and biofuel sector of Ghana. In total we undertook 14 interviews with different stakeholders that represented the main organisations involved in biofuel value chains in Ghana as identified in a previous review of the literature [33]

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(Table S1, Supplementary Electronic Material). These interviews captured their interpretation and definition of marginal land, as well as the locations and extent of such lands in Ghana.

Expert interviews were all semi-structured when it came to the questions asked about marginal land (i.e. we asked experts the same questions, with the same expression to allow for comparisons), and open-ended when it came to the answers received (i.e. respondents were allowed to elaborate freely with the authors only asking clarification questions where needed) (See Supplementary Electronic Material for the standardized questions about marginal lands). Each expert interview was transcribed and content analysis was used to identify key patterns between different stakeholders (Section 3.1). The keywords used for content analysis were informed by a literature review of the biofuel sector in Ghana undertaken by the authors [33], and a critical reading of the academic literature on marginal land for biofuel feedstocks [e.g. [11]]. Transcribed interviews were analysed using *Atlas.ti* software [34].

Household surveys (N = 106) were conducted around three collapsed jatropha projects (Section 2.2). These surveys captured general patterns about changes in the local community and the landscape following land conversion for jatropha production (see Supplementary Electronic Material for an overview of the household survey). This included questions about changes in access to different provisioning ecosystem services during the operation (i.e. post land-conversion) and after the collapse of each jatropha project. The first interval essentially captures the change in provisioning ecosystem services from the time of landscape conversion to the time of project collapse. The second time interval reflected changes from the time of collapse till the first fieldwork. Changes were captured using the following Likert-type scale [31]:

- 5 = increased significantly (denoted as ↑↑ as in Fig. 3)
- 4 = increased moderately (denoted as ↑ as in Fig. 3)
- 3 = remained the same (denoted as → as in Fig. 3)
- 2 = decreased moderately (denoted as ↓ as in Fig. 3)
- 1 = decreased significantly (denoted as ↓↓ as in Fig. 3)

For each ecosystem service and time interval, the response with the highest frequency was used in Fig. 3. Responses were visualised as patterns over time, with the deeper the colour in each individual cell of Fig. 3 reflecting a higher frequency of the response among community members. In a way, the deeper the colour the higher the frequency of an answer and the consensus about changes in the specific ecosystem service.

As our aim was to understand the effects of jatropha conversion to different members of the community we tried to capture the perceptions both of former plantation workers and community members not involved in plantations. This stems from previous work that has shown the differentiated benefits between these groups during the operation of jatropha projects in rural areas of SSA [31,35]. Former plantation workers were selected purposefully based on snowballing sampling. Other households not previously involved in the plantation were selected randomly after walking in the local community in order to increase the spatial distribution of the sample and cover as much of the landscape as possible. We interviewed either the household head or the spouse depending on availability. Interviews were solely with the respondent to avoid influence from other persons being present. Based on their responses, community members included a mix of landowners, migrant farmers, and ordinary native inhabitants. Approximately 63% (Kapchaa), 29% (Kobre) and 20% (Adidome) of the interviewed households gave out land. The above suggest that our sample is not representative of the community, but of the main livelihood options and landscape uses within each community, and spans the entire geography of each community.

Participatory field methods such as participatory mapping and FDGs [36,37], were used to obtain a richer understanding of landscape conversion processes, and how they affected the ecosystem services derived by the local communities. In total, we conducted 2 FGDs and 2 participatory mapping exercises in each study site, one involving male and one involving female respondents to capture gender-differentiated uses of the converted areas. The same community members were used for the participatory mapping and the FGDs. Participants were selected to represent the different groups identified during the household survey (i.e. landowners, migrant farmers, former plantation workers, ordinary native inhabitants) (see above).

Initially we conducted participatory mapping to gain a better understanding of the landscape conversion for jatropha production. This included a site investigation by the author team and a meeting during which local community members jointly drew maps of the location of major landscape elements such as landmarks, resource areas, conservation areas and infrastructure, and how these landscape elements changed during the conversion to jatropha (see Supplementary Electronic Material). This was an open and unstructured process that all participants provided input.

This was followed by FGDs that elicited the type of ecosystem services derived from the converted areas, before landscape conversion, during the operation of the project, and after the collapse of the project (i.e. during the time of the second fieldwork). This was a semi-structured group interview process following the questions provided in the Supplementary Electronic Material, and

Table 1
Data collection methods for primary and secondary data.

Data type	Fieldwork	Captured data	Mode of collection	Number	Sources
Primary	1st	- Interpretation and definition of marginal lands - Locations and extent of marginal lands	Expert interviews	14	Key stakeholders in the biofuel and land sector of Ghana (see Table S1 in Supplementary Electronic Material for a list of the interviewed stakeholders)
		- Households motivation to give out land - Use of land before giving it out and perceptions on land characteristics - Changes in access to ecosystem services during the operation and after the collapse of biofuel projects	Household survey	106	Households around three collapsed jatropha projects (e.g. landowners, former plantation workers, migrant farmers and native inhabitants)
	2nd	- Landscape modification for jatropha cultivation	Community mapping	3	Women and men that are members of the local communities
		- Ecosystem services derived from landscape before conversion and during the time of fieldwork	Focus group discussions	6	Women and men that are members of the local communities
Secondary	–	- Ecosystem services captured in EIA reports of biofuel projects	Literature review	3 reports	EIA reports of jatropha projects

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all participants offering information based on their experiences. Apart from the raw information (e.g. types of ecosystem services derived) we tried to capture instances of lack of consensus, but in all six FGDs was a broad consensus within the respective groups.

The results of the participatory mapping exercise were used to develop vector maps through GIS software [38]. Map digitization was done with *ArcMap 10.3* software (ESRI) using the base maps included in the software, and information provided by the participants of the community mapping, such as distances, landmarks, rivers, roads and settlement, and terrain inspection by the research team. It should be mentioned that while the digitized maps are approximate, they can provide interesting insights about landscape transformation and changes in land use and benefits derived (i.e. ecosystem services). The data collected from FGDs were coded using keywords that reflected the main ecosystem services affected by biofuel feedstock production in SSA as identified through a series of studies conducted by the research team [1,30,31,33]. Transcripts of the FDGs were analysed using *Atlas.ti* software [34].

Additionally we conducted interviews with the local chiefs to understand better the local communities, the processes of land acquisition and land conversion, and their impacts to the local communities. These were unstructured interviews used mainly to understand the local context. While these interviews have not been formally analysed as the expert interviews, they have provided valuable insights to put results into perspective.

Secondary data was collected through the EIA reports of the jatropha projects [30,40–52]. The purpose was to identify which ecosystem services were considered in the EIAs of the jatropha projects in the study sites. These were then compared with those identified through the FDGs and community mapping to further discuss whether these selected sites were correctly identified as marginal (Section 3.4).

2.2. Study areas

Primary data collection was conducted around three collapsed jatropha projects (Table 2). These jatropha projects were located on supposedly marginal lands as specified in their Environmental Impact Assessment (EIA) reports. These projects are a small subset of the more than 21 jatropha projects in Ghana that collapsed for a number of reasons, including low productivity due to poor site and crop selection [32] (Fig. 1).

To capture the wide variety of different ecosystem services affected from the conversion of supposedly marginal land for jatropha production in Ghana, we selected jatropha projects located in three major agro-ecological zones with different land tenure systems (Table 2).

For example, in Kpachaa, while chiefs are custodians of the land, individuals, families and clans own the land (northern Ghana system). In Adidome, land is generally in trust of the chiefs and not necessarily under individual ownership (southern Ghana system). Kobre, exhibits mixed characteristics as there are clear demarcations between chiefs and other landowners. In all of the selected cases, the landowners have usufructuary interest on the land, and most migrant farmers have shared tenancy and lease agreements.

Following the collapse of the projects, the formal land rights of the converted lands are still held by the jatropha companies. The land rights has thus toare not transferred to the local people and in theory these areas are out of bounds for the local communities. However, as the companies are not present any more in the areas some local people gain informal access to these lands by encroaching the areas for subsistence farming and livestock grazing.

3. Results

3.1. Definition of marginal land across stakeholder groups

A preliminary content analysis of Ghanaian agricultural policy documents conducted by the authors, suggested that there is a lack of formal definition of what constitutes marginal land in the country. While scientific publications on the interpretation of marginal land in Ghana are also limited, most authors generally take a food production narrative in their use of the term [6,48–50]. Some studies are optimistic about the availability of marginal lands and the ability to target them for biofuel production [48,51]. Yet, other studies are skeptical if such land exists in sufficient quantities in Ghana [52]. As a result, there are no legal, formal, or even informal documents that have demarcated areas considered as marginal and suitable for biofuels in the country. In view of this, different stakeholders understand and interpret the concept of marginal land differently, often to suit their own vested interests.

Table 3 summarises the perspectives of the main stakeholders involved in biofuel value chains in Ghana on what constitutes marginal land. In a nutshell there are two dominant perspectives about what constitutes marginal lands that, by and large, reflect the general definitions observed in the literature (Section 1): land marginal for food production and economically marginal land (see Table 3). To corroborate the lack of formal definitions, there is a consensus among all stakeholders interviewed that, there is no official or scientific definition of marginal land in Ghana that guides biofuel investments.

When it comes to the national level policy institutions, the land sector agencies (Lands Commission and TCPD) tend to describe marginal lands in economic terms, i.e. land that has limited competition with food production and is either not cost-effective or accessible for food production. Whereas some of the terms used to describe marginal lands also appear in some literature [11], nonetheless, they agree that such areas are not zoned in Ghana for biofuel production (or any other use for that matter). Other agencies such as MoFA, Energy Commission, and EPA mainly interpret marginal lands in terms of the food production limitations of land. Government agencies at the regional level seem to interpret marginal lands both in respect to their food production potential and economic status though there are difference in what is excluded from the definition of marginal lands between organisations (e.g. forest, wetlands), as shown in Table 3.

When it comes to civil society organisations, CSOs interpret marginal land solely in terms of food production limitations. This reflects to an extent their advocacy message for halting some biofuel projects in Ghana based largely on the “food vs fuel” and “land-grabbing” narratives, which has been a strong advocacy message for several CSOs in Ghana [e.g. [42-44]]. Oxfam for example suggested that the justification for choosing the location of a jatropha project should have been on the overall land requirement (not necessarily marginal land). Interestingly, CICOL rejected the idea that marginal land actually exists in any given context in Ghana given that there is neither an official definition nor a clear scientific basis. According to CICOL all lands have uses (whether predetermined or not) and competing uses (now or in the future). As a result, land cannot be very marginal as changes in land use can make it have competing uses later. This reflects well some of the findings of the application of ESA in the local communities (Section 3.3) as discussed in Section 4.

For the private sector, the interpretation of marginal land is generally aligned with the food production constraints narrative. Expert interviews with stakeholders from the private sector (Table 1) indicate that the potential limitations on food production represent the dominant justification for biofuel companies not only

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Table 2
Characteristics of the areas and communities around the three study jatropha projects.

Issues	Kpachaa	Kobre	Adidome
Administrative Region	Northern	Brong Ahafo	Volta
Coordinates	9°24′53.25″N 0°25′53.26″W	8°10′13.50″N 0°44′40.83″W	6° 5′4.35″N 0°33′6.89″E
Investor name	BioFuel Africa	Kimminic Corporation	Galton Agro Ltd
Investor Origin	Norway	Canada/Ghana	Israel
Year of Start based on [41,42]	2006	2007	2008
Year of Collapse based on [42]	2011	2012	2012
Land acquired/sold (km^2)	106.96	500.00	1000.00
Total land cultivated with jatropha (km^2)	10.00	10.50	3.25
Land cultivated with jatropha within study community (km^2)	6.33	2.9	2.6
Land cultivated with jatropha outside study community (km^2)	3.67	7.1	0.65
Ecological zone	Guinea savannah	Transitional forest	Deciduous forest
Previous land use	Cropland, woodland	Cropland, woodland	Cropland, woodland
Water management	Rainfed	Rainfed	Rainfed
Average temperature (°C)	14–40	27–40	16–30
Soil type	Voltarian sandstone	alluvial soils	Dahomeyan Acidic Gneiss
Annual rainfall (mm)	750–1050	800–1400	1000–1200
Incidence of poverty in study Districts (%)	35.3	41.9	46.0
Land acquisition process	Chief	Chief	Chief
Responsible for allocating land to investors	No	Yes	No
Consultation with local community	Only to few households	Only to few households	No
Compensation			
Company Land title type	Lease	Lease	Lease
Land rights of local people	Usufructuary share tenancy, lease	Usufructuary share tenancy, lease	Usufructuary share tenancy
Number of Focus Groups Discussions	2	2	2
Number of mapping exercise	1	1	1
Number of surveys	37	29	40
Surveys as fraction of local community (%)	33	8	19
Total Population	500	1344	1712*
Density at District level (Person/km^2)	29.9	40.1	40.7

Note: As of 2014, households in Ghana with an annual income below GH 1314 (US$328) are considered poor, and extremely poor when they earn below GH 792 (US$198) [47].
Source [41–47].

to gain access to wide tracts of land, but also to do so at low prices.

3.2. Land acquisition and conversion in study sites

In terms of the land acquisition procedures followed, interviews with the local chiefs in Kpachaa and Kobre suggest that the jatropha companies acquired the land directly from the chiefs, using middlemen. The companies subsequently obtained lease titles for 50 years from the Lands Commission. Whereas the chiefs claim that consultations with local communities were done (and the compensation paid), the majority of the local people claim that they were neither consulted, nor received compensation [53,54].

In Adidome, due to boundary disputes, the company allegedly acquired the land from the '*wrong*' chief and could not obtain a formal lease title as other affected communities claimed ownership of the land. These communities contested the case in court, which resulted in an injunction to prevent the company from registering it while the dispute was resolved. In all three cases the appropriate land acquisition procedures in national laws were not followed, which contributed to the collapse of all three projects through different mechanisms [53].

Household surveys indicate that local households gave to jatropha companies on average 8.1 ha in Kpachaa, 4.6 ha in Kobre and 6.5 ha in Adidome. In all study sites households gave out mainly farmland and fallow land, and secondarily woodland and grazing land. The findings of household surveys were confirmed during the subsequent FGDs and community mapping exercises, where participants asserted that most of the individual household land transferred to the plantation in each study site engulfed farmlands and fallow lands. In addition FGDs and participatory mapping showed that common land was also given to the plantation. Such common areas engulfed mainly water bodies, sacred groves, and forests (and secondarily grazing land).

Fig. 2 highlights the results of the community mapping exercise for each study site (a = Kpachaa, b = Kobre and c = Adidome). Due to the inherent uncertainties associated with community mapping, these maps should not be seen as perfectly fitting to scale, but instead as an indication of the main landscape elements lost during conversion to jatropha (see Table 2 for the actual land sizes of the three plantations).

3.3. Ecosystem services from converted land

Household surveys identified changes in the access to provisioning ecosystem services, during the operation and after the collapse of jatropha projects. Access to all provisioning ecosystem services considered in the household survey decreased during the operation of the project (Fig. 3). In most cases, this decrease was significant as self-reported by the respondents. With few exceptions, access to the lost ecosystem services was not reinstated after the collapse of the jatropha projects considering the extensive modification of the landscape. While the jatropha areas were out of bounds for local communities during their operation, some access to these areas is possible after their collapse but has not been formalized as the land still belongs to the jatropha company (Section 2.2).

FGDs with male and female participants were used to understand better landscape changes and the ecosystem services received, especially for non provisioning ecosystem services. FGD results are summarised in Table 4 and Figure S1 (Supplementary Electronic Material), with three main observations.

First, local communities identified a large number of provisioning and cultural ecosystem services they derived from the converted land prior to the establishment of the jatropha plantations (Table 4). Sometimes, FGD participants were also able to identify some regulating ecosystem services such as erosion and

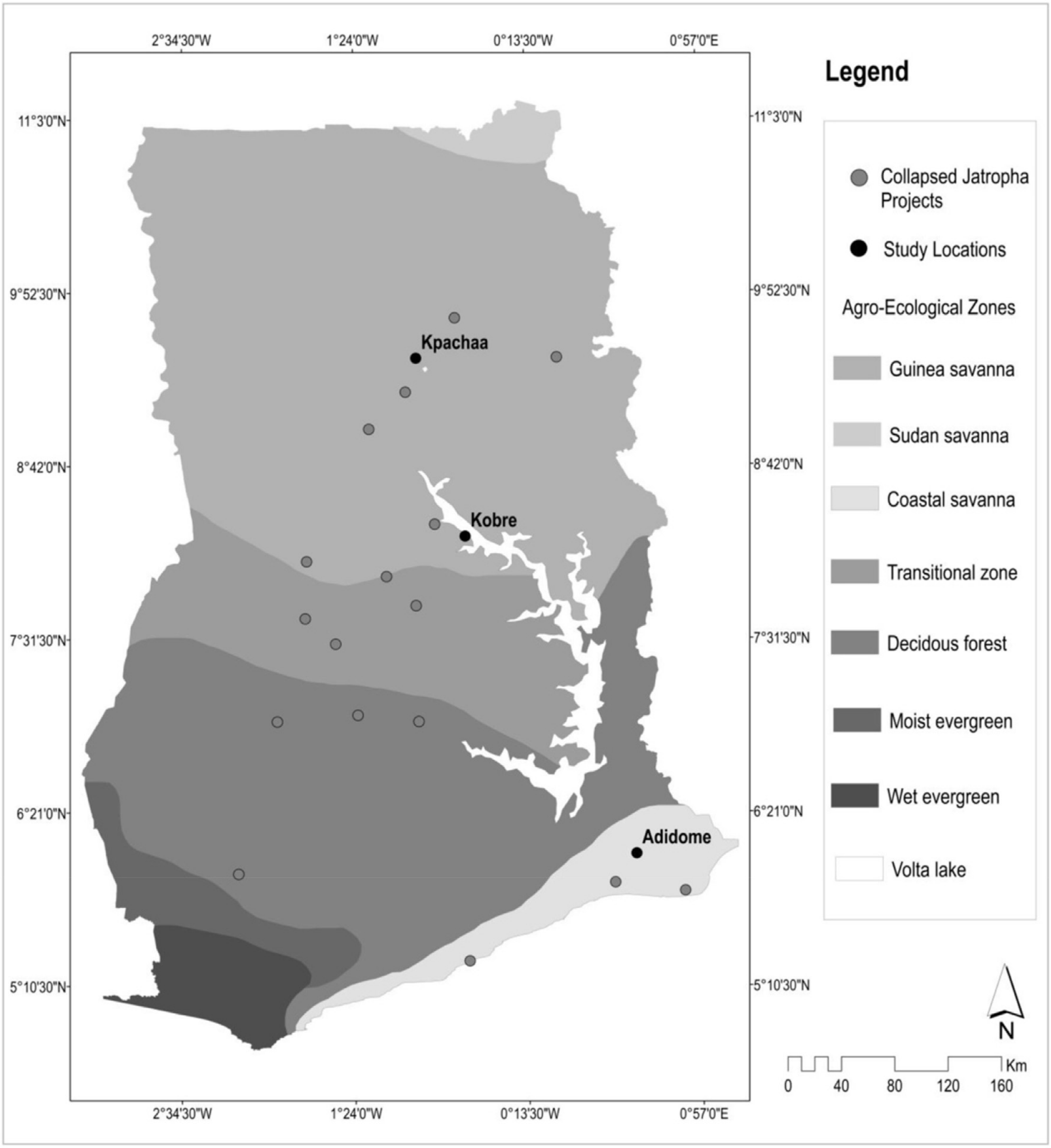

Fig. 1. Study sites and location of other collapsed jatropha projects across different ecological zone in GhanaNote.
Note that the projects included in this study are in bold on the map.

flood control. This suggests that while these lands were not highly productive for crop cultivation they still catered for multiple human needs.

Second, the variety of ecosystem services provided by the converted jatropha production land has declined after the conversion. The conversion of mixed landscapes containing agricultural land, forest and sacred groves to jatropha monocultures, not only simplified the landscape (Fig. 2) taking a toll on the variety of ecosystem services derived from it (Table 4). When it comes to provisioning services there has been a loss of numerous services related to wild food, construction materials and fuel. As access to such services has reduced (see also Section 3.2), members of the local communities now have to travel several kilometers to access water, cut fuelwood, obtain bush meat, or pick wild fruits. However, the converted areas still provide some level of provisioning services as some local people use jatropha leaves as a medicine and the milky sap as toothpaste (in Kpachaa and Kobre). The shaded areas under the plantation trees are a good habitat for termites that farmers collect and use as feed for poultry. In Kpachaa, the former plantation area is now encroached for grazing for livestock. In all areas, new trees (non-jatropha) growing in the converted areas are cut for fuelwood, though they are mostly immature. In some cases as Adidome, FGD participants lamented the lack of multiple uses for jatropha given that they do not have any direct use for the collapsed plantation.

The third observation has to do with the gender-differentiated access to some ecosystem services. While in some instances, both men and women commonly identify accessing the same ecosystem services, in other cases the types of ecosystem services derived from the same landscape differ significantly. For example, before the start of the projects, most women indicated accessing provisioning ecosystem services such as non-timber forest products

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Table 3
Definition of marginal land in Ghana as elicited through the 14 expert interviews.

Category	Stakeholder	Reference to food productivity	Reference to economically marginal	Terms used to classify marginal lands	Terms excluded (non-marginal)
National government	Lands Commission	–	Lands not in effective use, people are not interested to go and farm, low values and limited local competing uses	Too far from communities, development might not be achieved there in the near future (20–30 years), areas of scattered trees and shrubs	Forest, wetlands
	Ministry of Food and Agriculture (MoFA)	Not suitable for food production, low soil quality	Too expensive for subsistence farming	Degraded lands, abandoned lands,	Forest, wetlands, green space, range land, farmlands
	Energy Commission	Not fertile to an extent for food production	–	Degraded land, abandoned agricultural lands, surplus and idle in a given time	Forest, wetlands, green space, farmlands
	Town and Country Planning Department (TCPD)	Cannot be used for agriculture (food production and animal rearing)	Land values are low because of physical accessibility, cost of food production is high	Degraded, left over lands, barren, no competing localized uses, along highways, waste lands	Forest, conservation areas, native habitats
	Environmental Protection Agency (EPA)	Not fit for production of local staple foods	–	Degraded land, abandoned land	Forest, wetland
Regional government	Lands Commission, Northern region	Low soil quality and very poor yields	Too far from communities farmlands where it is not having competing uses now	Abandoned mines, sand wining pits	Land that will have competing uses for food in now and in future
	Lands Commission, Brong Ahafo region	Not suitable for food production	Not economically profitable for food production	Degraded land, abandoned land, idle land	–
	Ministry of Food and Agriculture, Brong Ahafo region	Not suitable for food production	No competition with food production	Surplus land after farming, land specifically identified as marginal	Forest, wetland, conservation areas
Civil society	Oxfam Ghana	Not suitable for food production	–	Desert or abandoned mines, idle, virgin, underutilized or vacant	Farmlands, fallow lands, wetlands, forest
	Action Aid Ghana	Low quality lands, poor yields	–	Abandoned mines	Rural agricultural lands
	Civil Society Coalition on Land*	–	–	–	–
	Trade Union Congress (Agricultural Workers Union)	Not suitable for selected food crops production	Too expensive to cultivate and not economically accessible	Abandoned mines, abandoned sand wining pits,	Idle lands, fallow lands, immediate community periphery
Private sector	Smart Oil Company Ltd.	Not suitable for cultivation, loss of soil fertility due to prolong farming	Cost of subsistence farming is too high,	Abandoned farming land, degraded lands, no competition with local food production, waste land	Forest, conservation areas, current farm lands
	CEHRT	Poor soil quality and not accessible	–	Stones, rocky areas, degraded lands, poor soils, water lock areas, flood plains, waste land	Forest

(NTFP), including wild fruits and medicinal plants used to supplement household food and income. On the other hand, men are mostly interested in land for food crop cultivation, which is a reflection of their role in these agrarian communities.

Regulating and cultural ecosystem services were mostly mentioned by women as shown in Table 4. These include spiritual and religious values associated with totems and sacred groves, as well as regulating services associated with landscape elements that are related to water conservation and flood regulation. In Adidome, for example, the converted land was a flood plain that used to regulate floods during rainy seasons. However, upon its conversion to a jatropha plantation, floodwaters are directed to the community and women are always the most affected community members as the FDGs suggest. Similarly, in Kobre, women believe that their reproductive cycle is tied to their totems such trees and animals, to which they were emotionally attached before the development of the plantation. Currently instances of infertility in the community are tied to the loss of these cultural services. Some of the observed disservices include the appearance of pests in Kobre, which initially invaded the jatropha plantation and later on farms in the local community.

Effects on supporting services did not come up in the FGDs, even though there was a question to tease them out. This does not mean that supporting services were not affected (which is highly possible given the extensive landscape modification), but that possibly respondents did not make the link. We hypothesise that this has to do with the fact that as supporting services underpin the provision of other final ecosystem services [27–29], they require a certain level of expertise and understanding of the system.

Finally, community mapping revealed that the loss of access to the area converted for jatropha production (and the ecosystem services it provided) led to increasing pressure on the unconverted surrounding land parcels. This led to the more rapid community appropriation of natural resources when compared to the natural replenishment rates. For example, in all study sites, the FDGs with women suggested that the trees felled and used for fuelwood or charcoal are increasingly less mature. FGDs with men also observed that the limited land availability in recent years has decreased their ability to do shifting cultivation, has shortened fallow periods, and reduced the expansion of farmlands.

3.4. Comparison of ESA findings and EIA reports

All EIA reports indicate that the jatropha plantations were eventually located in lands considered as marginal [39–41]. While there is not a straight definition of what is marginal land in these EIA reports, marginal land is interpreted as dryland with poor and degraded soils, deforested, and de-vegetated [39–41].

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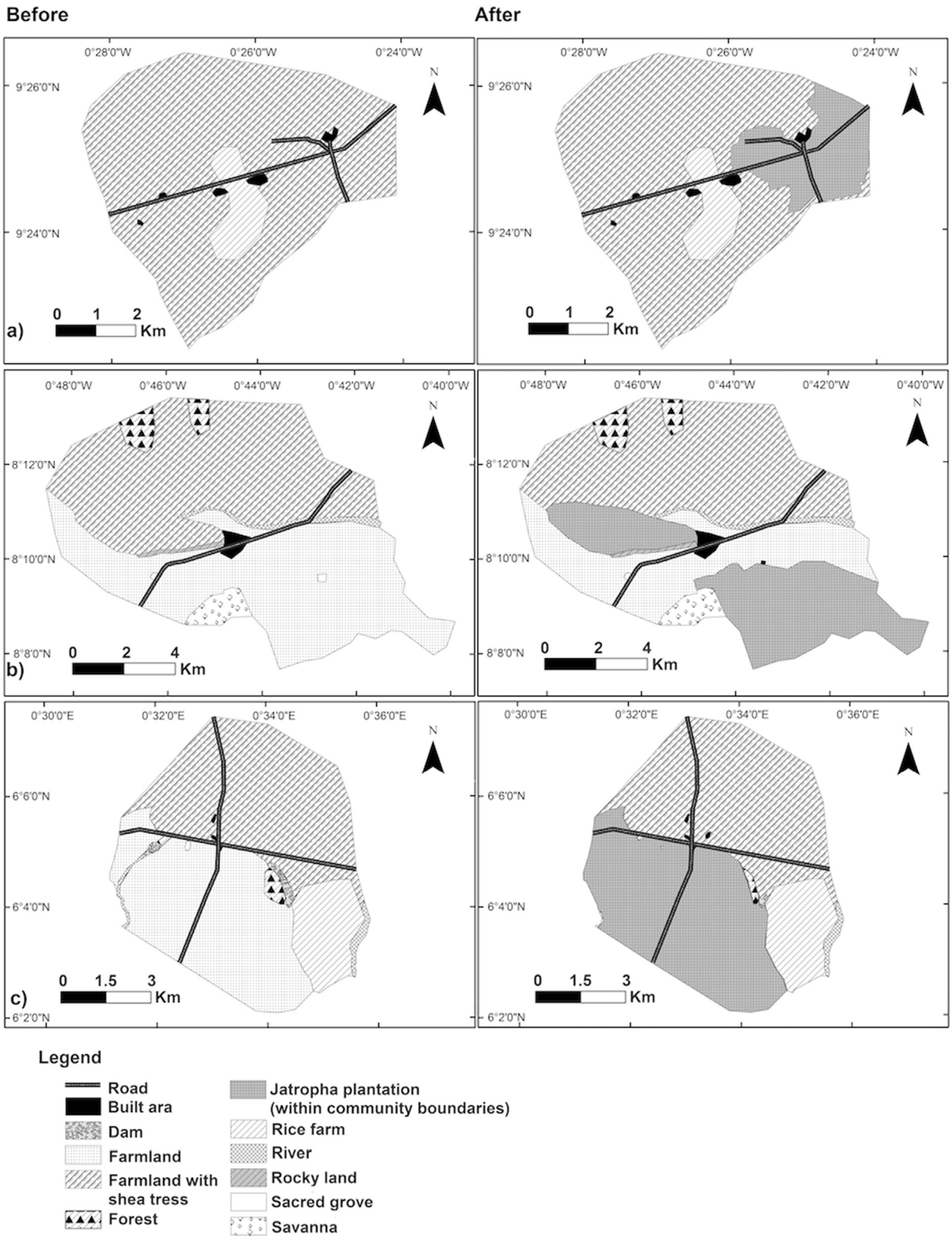

Fig. 2. Outcomes of the participatory mapping exercise for Kpachaa (2a), Kobre (2b) and Adidome (2c).

When comparing the ecosystem services identified through the FGDs and the impacts covered in the EIA reports some mismatches become evident (Table 5). In all EIA processes due consideration was not given to regulating and cultural services. This is a reflection of the current limitations in EIA scope given that it is limited to issues of provisioning services, habitats and issues that have to do with direct livelihood impacts.

On the contrary, communities benefit from ecosystem services beyond the services reflected in the EIA reports, most importantly cultural and regulating services such as flood control (e.g. in

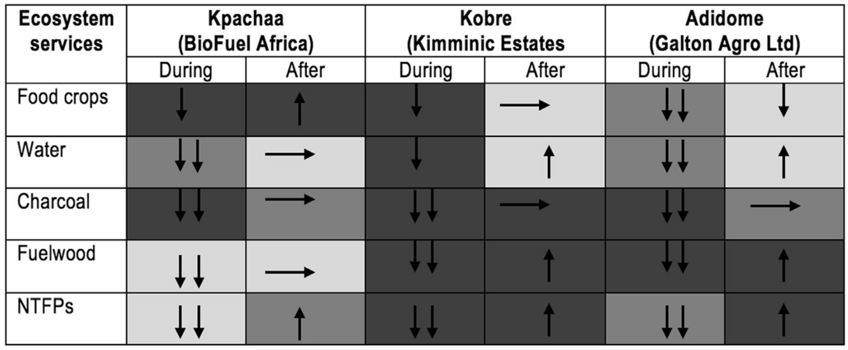

Fig. 3. Changes in provisioning ecosystem services during the operation and after the collapse of the three jatropha projects. Note: Arrows show direction of impact following the 5-level Likert scale (see Section 2.1). Depth of colour reflects the frequency of the most prevalent trend for all community respondents (Section 2.1). From deeper to lighter colours indicate frequencies of ≥80%, 60–79%, and 40–59%.

Adidome). The mismatch between the ecosystem services communities benefit from and those reflected in EIA reports is also seen in the proposed mitigation measures. Most EIA processes did not contain mitigation measures for ecosystem services that contribute indirectly to human wellbeing such as cultural and regulating services.

4. Discussion

4.1. Using the marginal land to determine the location of biofuel projects

During the biofuel boom in Ghana, the rush to attract FDIs overshadowed efforts to promote environmental safeguards. Even the draft guidelines on land acquisitions appeared in 2012, well after the collapse of most jatropha projects [55]. Several studies in Ghana have made the case that many of the negative impacts could have been mitigated if proper project planning procedures were duly followed [38,50,52]. What is really important to point out is that the marginal land narrative that was adopted as a means of identifying appropriate areas for biofuel production contributed to the emergence of these impacts as it created unrealistic expectations about (a) land availability and (b) the possibility to avoid competition with food production and other land uses (win-win expectations) [11].

In our opinion, the definition of marginal land as land unsuitable for cost-effective agricultural production (Table 3), offers a better interpretation than the definition as land unsuitable for food production. However, rather than resolving the “food vs fuel” debate, the current definition of marginal land (and the wider discourse) in Ghana (and elsewhere in SSA) reinforce productivism by legitimizing biofuel land deals at the expense of ecosystem services. Both interpretations in Ghana, and especially from agencies related to the land sector (i.e. Lands Commission), seem to reflect a new political discursive framework for land deals. These interpretations were used to create a new space for companies to get access to land using a language that supports productivism. At the local scale, marginal land in a way became an artificial spatial construct [7] to delineate land in a manner that neglects the multiple ecosystem services it offers.

Following this, several jatropha projects in Ghana were situated in marginal lands but eventually collapsed due to the low jatropha yields achieved under these marginal conditions [33,53]. This means that a paradoxical situation emerged. On the one hand marginal lands were targeted to increase the viability of jatropha projects by avoiding food-fuel competition (Section 1), but locating jatropha plantations in such area contributed to the downfall of these projects, leading to their collapse and taking in the process a toll on local livelihoods (Section 3.2–3.3) (see also [53]).

Section 3.3 makes obvious that even though jatropha projects were located in lands that were considered marginal based on the above definitions, the land was still providing various provisioning, regulating and cultural ecosystem services that met the needs of local communities and contributed to human wellbeing (Table 4, Table S1 Supplementary Electronic Material). Considering that poor rural communities in SSA depend significantly on ecosystem services for their livelihoods [56,57], this creates skepticism whether the two marginal land definitions discussed above are a valid lens to choose the location of biofuel projects.

By using the ESA it is possible to identify the multiple benefits derived from land, which are overlooked in the current marginal land definitions. The results in Section 3.3 reflect other studies in Ghana (and elsewhere in SSA), which have concluded that the land converted for jatropha production despite having been defined as marginal, actually catered for multiple human needs [15,50,51]. This was also hinted during the expert interviews with the Lands Commission, the TCPD and CICOL (Table 3). These stakeholders were skeptical about the possibility of having parcels of several thousand hectares in size of continuous marginal land following current definitions. These findings contradict to an extent studies that have identified degraded/marginal lands in large continuous tracts in Africa [19,23,24].

While this paper focused on jatropha some of the main points can be valid and for other biofuel crops that have been identified as fit for marginal lands in Africa such as sweet sorghum and moringa [58]. Such crops are touted as possible alternatives to meet the void left by the collapse of jatropha in SSA, but little is know about the capacity to provide sufficient yields under marginal conditions, as well as their competition with other ecosystem services in such contexts [59]. While their multi-functional nature might allow them provide more ecosystem services compared to jatropha, a good understanding of such trade-offs in marginal contexts remain a big gap in the literature that need to be to explored if the negative experience with jatropha expansion in SSA is not to be repeated.

All of the above point to the need to reconsider the concept of marginal land for selecting the location of biofuel projects. In our view, we must move away from the current marginal land discourse and reflect ecosystem service trade-offs during the project planning and site selection (Section 4.2).

4.2. Using the ESA for biofuel project planning: implications and ways forward

Our results suggest that the ESA can inform site selection for

Table 4
Ecosystem services derived from the converted area before jatropha conversion and at time of fieldwork in the three study sites for land acquired and planted.

Phase	Ecosystem service category	Kpachaa (Biofuel Africa)		Kobre (Kimminic)		Adidome (Galton Agro Ltd)	
		Men	Women	Men	Women	Men	Women
Before conversion	Provisioning	- Food (food crops) - Wild food (e.g. bush meat) - Sand (for houses) - Grass (for houses) - Mud (for houses) - Livestock grazing - Termites (for poultry feed) - Freshwater (for small-scale irrigation)	- Food (food crops) - Fiber (from trees for basket weaving) - Fuelwood - Charcoal - Medicinal plants - Grass (for basket-making) - Wild food (e.g. Shitumu caterpillars)	- Food (food crops) - Bush meat - Medicinal plants - Fuelwood - Charcoal - Sand (for houses) - Livestock grazing - Freshwater (for small-scale irrigation)	- Food (food crops) - Medicinal plants - Fuelwood - Charcoal - Freshwater (for household consumption) - Wild food (e.g. shea and Shitumu caterpillars	- Food (food crops) - Livestock grazing - Medicinal plants - Fuelwood - Charcoal - Sand (for houses) - Freshwater (for small-scale irrigation)	- Food (food crops during dry season farming) - Wild food (e.g. shea) - Material for foodstuff (e.g. baobab leaves, Dawadawa fruits) - Medicinal plants - Fuelwood - Charcoal
	Regulating	- Temperature regulation (cooling for humans during hot season)	–	- Fresh air - Cool air for livestock	- Water retention during rainfall - Erosion control - Prevention of loss of top soil nutrients - Fresh air	–	- Trees as windbreaks - Flood regulation
	Cultural	- Worship in sacred groves (religious values) - Trees and animals as Totem (spiritual values) - Enjoying nature (aesthetic values)	- Worship in sacred groves (religious values) - Teach children traditional knowledge (knowledge)	- Worship in sacred groves (religious values) - Trees and animals as Totem (spiritual values) - Enjoying nature (aesthetic values) - Teach children traditional knowledge (knowledge)	- Worship in sacred groves (religious values) - Recreation for children (recreational values)	- Worship in sacred groves (religious values) - Teach children traditional knowledge (knowledge)	- Worship in sacred groves (religious values) - Trees and animals as Totem (spiritual values) - Teach children traditional knowledge (knowledge)
During operation	Provisioning	–	–	–	–	–	–
	Regulating	–	–	–	–	–	–
	Cultural	–	–	–	–	–	–
After collapse	Provisioning	- Food (food crops) - Termites collection for poultry feed - Livestock grazing	- Jatropha leaves as medicine	- Food (food crops) - Freshwater - Fuelwood - Livestock grazing - Jatropha milky sap (as toothpaste)	- Food (food crops) - Freshwater - Fuelwood - Jatropha leaves (as medicine)	- Food (food crops) - Freshwater - Fuelwood	- Food (food crops) - Freshwater - Fuelwood
	Regulating	- Cool air for livestock	–	- Cool air for livestock	–	- Cool air for livestock	- Cool air for livestock
	Cultural	–	–	–	–	–	–

Note: During the operation of the jatropha plantations the areas were off limits for local communities. As a result no ecosystems services were obtained from these areas. Food, freshwater, livestock grazing and fuelwood were obtained after collapse through encroachment and always in lower quantities compared to before conversion.

Table 5
Comparison of the ecosystem services derived by local communities before landscape conversion (elicited through FGDs) and expected impacts included in EIA reports.

Ecosystem Services	EIA Reports			FGDs		
	Kobre (Kimminic Estates)	Kpachaa (BioFuel Africa)	Adidome (Galton Agro Ltd)	Kobre (Kimminic Estates)	Kpachaa (BioFuel Africa)	Adidome (Galton Agro Ltd)
Provisioning	✓	✓	✓	✓	✓	✓
Food						
Water	✓		✓	✓	✓	✓
Wood & fiber	✓	✓	✓	✓	✓	✓
Fuelwood	✓	✓	✓	✓	✓	✓
Medicinal plants	✓	✓	✓	✓	✓	✓
Regulating	X	X	X	X	X	✓
Water purification						
Disease control	X	X	X	X	X	X
Flood regulation	X	X	X	X	X	✓
Climate regulation	✓	✓	✓	✓	✓	✓
Cultural	X	X	X	✓	✓	✓
Spiritual						
Educational	X	X	X	✓	✓	✓
Recreation	X	X	X	✓		✓
Aesthetics		✓	✓	✓	✓	✓

Note: ✓ = presence and evidence reported: X = No presence and/or evidence reported.
Source [39–41]: and FGDs

biofuel crops. In particular it can allow for a better understanding of the multiple uses and benefits provided by marginal lands. This can provide baseline information to make an informed decision about the actual trade-offs expected to emerge by converting such marginal lands for feedstock production.

During the early phases of biofuel project planning (i.e. before site selection), it is important to identify in the areas earmarked for biofuel development the different land use features/elements likely to provide ecosystem services to local communities. Then by using the ESA in a collaborative manner between experts and local communities, it can become possible to identify the different services provided by the land to be converted and classify it appropriately. The central idea is that site selection can be better informed by using the ESA compared to the simplistic approach of the current definitions of marginal land. This can prevent the conversion of areas that are hotspots for the provision of ecosystem services, or at least to provide a better basis for designing compensation mechanisms if it is unavoidable to convert important landscape elements.

This proposal shifts from the productivism perspective of the marginal land narrative (Section 4.1) to one that prioritizes the identification and categorization other values that are provided so that tradeoffs can be more clearly understood during the decision making process. The ESA inherently acknowledges that trade-offs do exist and that they must be managed in order not to take an inadvertent toll on the livelihoods of local communities. However, there are important policy and practice gaps that hinder the adoption of ESA for biofuel project planning in Ghana (and possibly elsewhere in SSA).

When it comes to policy gaps, the current system of obtaining a license to operate a biofuel project in Ghana or the guidelines for large-scale land acquisitions do not address issues related to ecosystem services [33,60]. A way to integrate ecosystem services in biofuel policies could be for agro-ecological zoning and land classification to also consider the potential of the mapped areas to provide ecosystem services. Even though using the ecosystem services approach will not preclude the emergence of trade-offs, as any landscape conversion will inevitably lead to some ecosystem services trade-offs, it will make them more visible to decision-makers whether in a qualitative manner (as is in done in this study with the identification of obtained ecosystem services pre- and post-conversion) or a more quantitative manner [61]. This is an important step considering that such trade-offs are usually hidden within the current marginal land policy discourse. In any case this would require significant revision in the land administration system in Ghana that has been plagued by minimal reforms [62]. Ultimately, this could be a good way to improve the land policies that shape the relationship between landowners and state interests that historically offered only marginal benefits to local landowners in Ghana [51].

When it comes to practice gaps, current EIAs practices have been criticized as inadequate to offer a good representation of the ecosystem services effects of landscape conversion [67]. Actually this reflects general criticisms of the narrow scope of EIAs, especially related to the impacts considered, and especially indirect impacts [63,64]. Unfortunately, our comparison of FGD results and EIA reports (Section 3.4) confirms these criticisms as that there has been a mismatch between the ecosystem services communities benefited from, and those reflected in the impacts considered in the EIA reports [39,40,41,65]. As EIAa is one of the few opportunities that local communities voices can be heard during biofuel project planning in Ghana [65], it is imperative to add modules on ecosystem services in bioenergy-related EIA processes [e.g. [66]], especially in projects expected to be located in marginal lands. Expanding in such a way the scope of current EIAs with elements of the ESA can enrich the process of biofuel project planning [67]. Expanding the EIA scope must not only be concerned with widening assessment criteria (e.g. including provisions for cultural and regulating services) [see also similar point at [68]], but also the process itself to allow for the greater involvement of affected communities.

5. Conclusions

This paper discusses the considerable limitations of the current marginal land discourse to inform biofuel project planning. Initially, through expert interviews with key biofuel stakeholders in Ghana we identified the different interpretations of marginal land in the country (land unsuitable for food production vs land unsuitable for cost-effective agricultural production). Subsequently household surveys, community mapping and FGDs in three communities around collapsed jatropha projects identified the multiple ecosystem services that local communities derived from the land prior its conversion in jatropha monocultures. Several of these ecosystem services were lost after land conversion taking a toll on local livelihoods.

As most of these ecosystem services are not considered in the current marginal land discourse (apart from food crops), we highlight the significant limitations of the current discourse for guiding site selection appropriate for biofuel production. We argue that the ESA can offer a better understanding of the landscape and its uses, thus being a better lens to inform the location setting of biofuel. Even though using the ecosystem services approach will not preclude the emergence of trade-offs, as any landscape conversion will inevitably lead to some ecosystem services trade-offs, it will make them more visible to decision-makers as they are not lost in the prevailing marginal land discourse.

To achieve this we propose the expansion of the current scope of EIAs for bioenergy projects to embrace insights from the ESA. Apart from the inherently wider criteria/perspective the ESA uses compared to current definitions of marginal land, the ESA can catalyze a deeper involvement of local communities in site selection as this could overcome the expert biases in the interpretation of marginal land.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.biombioe.2017.07.020

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