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A Participatory Scenario and Spatially Explicit Approach for Envisioning the Future scenarios of Land-Use/Land-cover Change on Ecosystem Service Provisioning to Inform Sustainable Landscape Management: The Case of Coastal Southwestern Ghana

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Abstract

Land-use changes such as settlement and commercial agricultural land expansion heavily influence the sustainability of landscapes and ecosystem service (ES) provisioning. Land managers and decision-makers are becoming increasingly concerned about the consequences of land-use change and advocate for integrated approaches to landscape sustainability. Integrated landscape approaches, which incorporate stakeholder views and opinions, are less explored. Especially in sub-Saharan Africa (SSA), where most of the population relies on natural resources and agricultural land-use products, integrating stakeholder knowledge in evaluating ES and landscape sustainability remain less studied. This study applied a participatory scenario-building approach combined with a spatially explicit simulation to unravel the impact of potential future scenarios based on a business-as-usual (BAU) trajectory of the coastal landscapes in southwestern Ghana. Through workshops, the perceptions of the land-use actors on locally relevant ES, ES indicator values, and the specific simulation conditions of the major land-use change, which is the expansions in rubber plantations (out-grower scheme) and settlements, were identified. The collected local knowledge was integrated into a spatially explicit modeling platform, allowing the visualization and comparison of different scenario impacts, such as synergies or trade-offs between ES. The results presented how land-use actors' perceptions could influence the landscape capacity of ES provisioning. The results indicated risk in ES delivery and landscape sustainability challenges, hence calling for effective land-use policies to control socio-economic activities and increase diversity in land-use under sustainable landscape development.

1. Introduction

Ecosystem services (ES), such as food, energy, regulation of soil quality, and climate regulation, provide the basis for human well-being; hence the sustainability of ES has become a global priority (Costanza et al., 1997; Gerten et al., 2015; Talbot et al., 2018). ES integrity, status, and capacity are heavily influenced by land-use/land-cover changes(LULCC) (Nelson et al., 2010; Polasky et al., 2011). For example, urbanization, and commercial agricultural expansions, associated with rapid economic development, are the main factors that increase the pressure of key ES (Tolessa et al., 2017; Ye et al., 2018; Zhang et al., 2015). In addition, a consequence of the LULCC has been the reduction of biotic diversity that has undermined the ability of the ecosystems to continue providing goods and services to humanity for future generations (De Groot et al., 2012; Mendoza-González et al., 2012; Metzger et al., 2006). Humans drive LULCC through land-use decisions from the local to the national level. In turn, environmental degradation, the impacts of climate change, and a decrease in ES provision have become the consequences of the LULCC. Hence the cause of LULCC and its effects should be understood as a social-ecological process within the landscape sustainability agenda (Magliocca et al., 2015; Ren et al., 2019; Verburg et al., 2015). LULCC has merited considerable attention in the landscape sustainability agenda due to the potentially negative consequences of LULCC on ecosystem service status (Magliocca et al., 2015). For example, the ecosystem service value (ESV) for the Lake Malombe catchment area (Malawi) declined due to considerable loss in Malawi's forest, water body, and marshy regions (Makwinja et al., 2021). In Ethiopia, changes in land-use and land degradation have contributed to about 17.7% loss in ESV (Sutton et al., 2016). The invasion of *Prosopis juliflora*, one of the world's worst invasive species, was found to have accounted for the decline in bush-shrub-land and grassland in the Afar region of Ethiopia and consequently reducing the ES provided by these land-cover types at an annual loss of US$602 million (Shiferaw et al., 2019). Specifically in Ghana, urban expansion resulted in a decline in the natural environment from 41–15% for 27 years and led to the decline in ES provisioning such as carbon storage, avoided runoff, and regulation of soil quality (Puplampu & Boafo, 2021). The disruption of ecosystem services caused by LULCC necessitates that LULCC is incorporated into addressing sustainability challenges related to land management, climate change adaptation, food security, biodiversity, and cultural preservation (Meyfroidt et al., 2018). Therefore, studies on how land-use changes will affect the Ecosystem are essential under sustainable landscape discourses (Rounsevell et al., 2012).

Scenario development is one of the suitable methods for visualizing and planning the potential future scenario of land-use change. It offers the possibility to explore and assess the potential impacts of land-use change and the associated environmental, social, ecological, and economic consequences (Kriegler et al., 2012; Reed et al., 2013). Scenario development also offers the platform to develop potential solutions to address identified environmental problems, thereby supporting decision-making processes (Kariuki et al., 2021). Land-use decision-making and scenario development often advocate for the inclusion of not only scientific researchers but also the participation of land-use actors (Davenport et al., 2019; Mallampalli et al., 2016). The reason has been that land-use decision-making processes are often challenging to develop and implement. It requires diverse knowledge types, multi-actor and multi-sector negotiations on trade-offs and synergies in land-use while tackling data scarcity and communication gaps. These challenges mentioned above are overcome mainly by including stakeholders in land-use decision-making processes (Bohunovsky et al., 2011; Gorddard et al., 2016; Gray et al., 2015; Reed et al., 2013). Participatory approaches in land-use scenario developments offer the possibility to discuss diverse opinions and deliberate and negotiate on issues to reach a consensus (Chaudhury et al., 2013; Johnson et al., 2012). Thus participatory scenario development is a relevant tool for researchers to unravel inherent information in a specific context, helpful in addressing the complexities and uncertainties in land-use decision-making and forecasting environmental change (Swetnam et al., 2011). Participating with diverse stakeholders in scenario development contributes to scenarios' credibility, quality, relevance, and legitimacy, primarily when the process and outputs are understood by all participants, creating a sense of ownership (Davenport et al., 2019, Reid et al., 2016).

Participatory scenario development has been applied in several land-use change studies: in the study of mosaic landscape sustainability (Asubonteng et al., 2021), community forest management and livelihood (Gobeze et al., 2009; Kassa et al., 2009; Sheppard, 2005), land-use change impacts on ecosystems (Patel et al., 2007; Plieninger et al., 2013; Swetnam et al., 2011; Walz et al., 2007), conservation of protected areas (Malek & Boerboom, 2015; Palomo et al., 2011) among others. However, the integration of spatially explicit simulation of actors' views and opinions on current and future scenarios of land-use change and its likely effects on ES remains understudied, especially in the context of sub-Saharan Africa (SSA) with the study of Koo et al. (2019) among the exception. Such a study is of high relevance in SSA's coastal landscapes, where rich biodiversity, spatial heterogeneity, natural resource endowment, resource management conflicts, high urbanization and industrialization processes exist. In addition, spatially explicit simulations help to identify likely areas critical of change (Ren et al., 2019). Combining LULCC scenarios generated by actors' perceptions with spatially explicit land-cover models provides a consistent, logical, transparent, and replicable framework for land-use planning and management (Nicholson et al., 2019). Unfortunately, Ghana has been faced with numerous challenges of insufficient or low compliance levels with land-use planning and management requirements, specifically due to low participation of stakeholder groups, weak enforcement provisions, and limited measures taken to address the concerns of an increasingly dynamic society (Akaateba et al., 2018; Awuah et al., 2014; Awuah & Hammond, 2014). In other studies in the Ghanaian context, the formulation of land-use plans has been extensively criticized. The process is regarded as driven mainly by experts, with little or no focus on addressing the broad stakeholder groups' rights, interests, and claims (Poku-Boansi & Cobbinah, 2018).

Given stakeholder perceptions' critical role in sustainable landscape development, and the research gap in SSA and Ghana, this study uses perceptions and opinions to simulate the plausible future scenario of land-use change. The study assesses the impacts of LULCC on ES in coastal southwestern Ghan. The study landscape is known for its socio-economic activities, mainly rubber plantation expansions through out-grower schemes and settlement expansions from oil discovery development (Asante-Yeboah et al., 2022; Bugri & Yeboah, 2017). The study addresses four research questions: i) How do the land-use actors perceive the current landscape to provide locally relevant ES?, ii) How do land-use actors perceive a future landscape to provide ES under a business-as-usual 'BAU' scenario? iii) What challenges do the land-use actors perceive in the capacity of ES provisioning under the 'BAU' scenario? And v) What appropriate actions are needed for sustainable landscape development?

2. Material And Methods

2.1 Study area

The study area is the Ahanta West Municipal Assembly (AWMA), located in the southernmost part of Ghana (Fig. 1). AWMA has a total population of 138,192 and covers an area of 591 km^2 (GSS, 2019). Geographically, AWMA lies between latitude 4^{0}45'00" N and 4^{0}57'00" N and longitude 1^{0}45'00" W and 2^{0}13'00" W. In AWMA, most of the land is flat and covered with tropical rainforest vegetation. AWMA borders the Gulf of Guinea in the south, the oil city Sekondi–Takoradi Metropolitan Assembly (STMA) to the east, Nzema East to the west, and Mpohor Wassa East District to the north (Fig. 6-Appendix). AWMA is one of the wettest places in Ghana, with a bimodal rainfall pattern: wet and dry seasons (AWMA, 2018). The region's dendritic drainage pattern positively impacts agricultural activities and other livelihoods (Bessah et al., 2021). From the aspect of national development, this region possesses rich reserves of natural resources, which functions as a critical economic player (AWMA, 2018). There is a large rubber and oil palm industry in the region. Commercial quantities in oil discovery and associated onshore infrastructural development have induced various socio-economic activities in recent years which have pressured the land and the surrounding natural environment (Bugri & Yeboah, 2017; Otchere-Darko & Ovadia, 2020). The loss of the coastal landscape due to replacing natural habitat with mono-cropping fields and infrastructures according to social demands potentially threatens biodiversity and ecosystem functions (de Graft-Johnson et al., 2010). However, ES and landscape sustainability have rarely been considered in Ghanaian spatial planning and development programs (Inkoom et al., 2017).

2.2 Integrative assessment framework

Figure 2 presents the steps of the participatory scenario-building and spatially explicit simulation employed in this study. The assessment process consists of 4 steps. Step 1 (S1) describes the current status of land-use patterns and ES, Step 2 (S2) explains the development of the future land-use scenarios and simulation conditions. Step 3(S3) is the data analysis part, which assesses the impact of future land-use scenarios. Finally, Step 4(S4) describes the participatory visualization and deliberations on the outcomes of the simulations.

Through stakeholder workshops, this study involved land-use actors such as local direct land users, institutional actors, and industrial actors and captured their collective perception of the landscape, reflecting on the current state and the actors anticipated future state (Allan et al., 2022; Villamor et al., 2014). In terms of selecting the actors, first, we applied stratified sampling to include only actors with a direct interest in using the land-cover types on the study landscape. Secondly, within each actor group, in consultation with the respective head/leader, we randomly selected at least two persons for the workshop. We randomly chose workshop participants considering their knowledge and interest in land-use activities. Six farmers, two chiefs, eight institutional actors, and five industrial actors participated in the workshop.

Two workshops were held between March and May 2021. The collected local knowledge was combined with spatial data in GISCAME (GIS = geographic information system, CA = cellular automaton, ME = multi-criteria evaluation), which is a landscape planning modeling software that can analyze how land management decisions can affect the landscape service and functions using a perception-based approach ((Fürst et al., 2010; Koschke et al., 2012).

2.3. Current status of land-use patterns and ecosystem services

2.3.1. Description of land-use patterns

The land-cover map was the primary input for the spatial simulation process. The study relied on a categorial land-cover map of AWMA produced from satellite images captured in 2020 using GIS and Remote sensing methodologies (Asante-Yeboah et al., 2022). The generation of the land-cover map consisted of 8 main land-cover types (Table 1). AWMA is dominated by a smallholder-agrarian landscape related to the main livelihood of the local people. The primary farming type is mixed cropping, combining a staple crop, e.g., cassava, plantain, yam, with green vegetables and legumes, which aims to meet household food demands and dietary needs. The landscape has about 22.26% of its surface area occupied with cropland (Table 1). In addition, the climatic condition and soil characteristics of AWMA make it suitable for cultivating economically viable crops such as rubber and oil palm. Rubber covered an area of 27.35%, while palm occupied an area of 19.67%.

Table 1
Description of land-cover types in the study area and land share (Asante-Yeboah et al., 2022)

Land-cover types	Description	Percentage of area(%)
Settlement	Rural communities, residential areas, industrial areas, and bare concrete grounds, roads, and other artificial structures	7.61
Rubber	Rubber (plantations and out-grower schemes)	27.35
Palm	Oil palm fields (smallholder and large-scale plantations) and coconut fields.	19.67
Cropland	Annual and biannual food-crop farms, such as plantain, cassava, cocoyam, and vegetables	22.26
Forest	Cape Three Points Forest Reserve	9.09
Shrubland	Woody vegetation includes open areas, bushes, and fallow lands.	11.46
Waterbody	Rivers	0.55
Wetlands	Wetlands with mangroves	2.00

2.3.2 Identification of ecosystem services status

Firstly, an initial set of ES was selected from the list of the Common International Classification of Ecosystem Services (CICES V5.1). The ES aligned with the benefits and predominant uses of the smallholder mosaic landscapes in developing countries (Table A1-Appendix). Then, locally relevant ES to the study landscape and their indicator values were identified through a stakeholder workshop (S1 of Fig. 2). The workshop began with an introductory presentation on the current state of the study landscape (refer to. Asante-Yeboah et al., 2022). Next, participants were tasked to identify the locally relevant and significant ES that reflects their livelihood needs using a Likert scale of 0–5 (from 0 = not relevant at all to 5 = highly relevant) (refer to Online Resource 1). A final set of ES used in this study was selected, which showed an average Likert scale value above 4 (Table 2).

In addition, indicator values of the selected ES were derived through the actors' perceptions of the capacity of different land-use types to provide each ES with a Likert scale of 0–5 (from 0 = no capacity to 5 = very high capacity) (refer to Online Resource 2). Regarding ES directly obtained from land-use activities as tangible benefits, e.g., food, fuelwood, and marketable products, identifying indicators for the ES using local perceptions were feasible. However, using local perceptions, indicator values for two indirect ES (species diversity and soil quality regulation) were hard to capture. Alternatively, we applied expert opinion through the Delphi method and Shannon Wiener diversity index to estimate the indicator values for soil quality regulation and species diversity, respectively. The Delphi method is proper when there is huge time demand to collect sufficient field data (Walters et al., 2021). In this study, we engaged six experts knowledgeable about the characteristics of the ecological zone and land-cover types of the study area for generating a proxy value for soil quality regulation. Species diversity/biodiversity was estimated using the Shannon-Wiener diversity index with a sample count of species from each land-cover type. The Shannon-Wiener diversity index is widely used in environmental studies, especially for comparing two or more environments simultaneously (Omayio & Mzungu, 2019). The species data were obtained from the organizations responsible for the identified land-cover types (e.g., GREL for the rubber plantation firm, Normpalm for the oil palm industry, MOFA for cropland, Forestry Commission for the forest, and Physical planning unity for open spaces).

Table 2
Selected locally relevant ecosystem services, indicators and proxies, and data generation methods used in the study.

Ecosystem services	**Description**	**Indicator/proxy**	**Data source**	**Reference**
Food provision	Use of cultivated plants and animals for human nutrition	The proportion of land-use products used as food for human consumption (%)	workshop	(Haines-Young & Potschin-Young, 2018)
Marketable products	Use of land-use products to generate household income	The proportion of land-use type use sold for income (%)	workshop	(Haines-Young & Potschin-Young, 2018; Koo et al., 2019)
Fuelwood provision	Use of the land-use product for household energy/cooking	The proportion of land-use products used as fuelwood (%)	workshop	(Haines-Young & Potschin-Young, 2018; Schmidt et al., 2019)
Soil quality Regulation	Decomposition process and effect on soil quality	The litter decomposition rate of land-use type (%)	Expert survey through the Delphi method.	(Haines-Young & Potschin-Young, 2018)
Species diversity	The benefit of land-use types to produce seeds, spores and other plant materials for maintaining or establishing a population of plant and animals	Type of species and amount of varieties existed in each Land-use type (Shannon diversity index)	Secondary data, expert survey,	(Haines-Young & Potschin-Young, 2018; Omayio & Mzungu, 2019)

2.4 Development of future land-use scenarios and simulation conditions

This study focused on perception-based forecasting and spatially explicit simulations based on the collected information through a scenario-building workshop. Participatory forecasting evaluates the current conditions and predicts the likely future without intervention (Petropoulos et al., 2022). The workshop engaged participants in discussing the plausible future landscape scenario under a Business-as-usual (BAU) trajectory. Expanding rubber plantations and settlements were considered the BAU drivers for LULCC. The local perception was specifically collected to elaborate spatial transition rule-sets for simulating scenarios (S2 of Fig. 2). For instance, the participants were asked about the probability (%) of the change from one land-use type to rubber or settlement, considering the current state of land-use and without policy intervention. A Likert scale of 0-100 (75–100%- Extremely probable, 51–74%: very probable, 31–50%: probable, 11–30%: Not so probable, 0–10%:Not probable) was used to identify the likelihood of individual conversion from current land-use type to rubber or settlement related land-use types (refer to Online Resource 3). In addition, neighboring land-use types were discussed, which are helpful in considering proximity effects to influence land-use changes.

2.5 Data analysis (impact assessment of future land-use scenarios)

Simulation and scenario impact analysis was conducted using the GISCAME modeling platform consisting of GIS modules, a Cellular Automaton (CA) module, and a multi-criteria ES assessment matrix (S3 of Fig. 2). GISCAME is an effective tool for visualizing ES provided by current and simulated land-use patterns and comparing scenario impacts which are presented as trade-offs or synergies between ES options (Fürst et al., 2011a, 2013; Koo et al., 2019; Koschke et al., 2012).

The indicator values provided by the participants for each land-cover type (see 2.3.2) were standardized with value ranges between 0 (minimal potential of land-cover type to provide the relevant ES) to 100 (the maximum potential of a land-cover type to provide the relevant ES) following the works of (Fürst et al., 2011b; Koo et al., 2018, 2019; Koschke et al., 2012). The standardized values comprised an ES assessment matrix that presents the relationship between land-cover types and their capacity to provide ES with the same value unit. Developed BAU trajectory-based scenarios (see 2.4) were simulated using a CA. CA is a discrete dynamic cell base system that converts the state of a cell based on a rule-set regarding its neighboring cells and its own environmental status (Koo et al., 2018; Koschke et al., 2013). The transition rule-sets can be iteratively applied in the GISCAME for many time steps to show the impacts of temporal or intensification of land-use changes. In this study, the application of the transition probabilities was agreed upon with the stakeholders as one iteration to simulate five years from the current state and ten iterations to simulate 50 years into the future from the current state.

Newly generated land-use patterns by the CA process were combined with the ES assessment matrix to show the capacity of the study area to provide ES. The final assessment score indicates mean values for the ES provided by individual land-use cells within the area (Koo et al., 2019). The spider chart, the ES provisioning map, and the ES balance table represented the final outputs. By comparing the mean ES values provided by current and future land-use patterns, potential trade-offs or synergies between ES caused by land-use changes at the landscape level were identified.

The assessed results were shared and discussed with the land-use actors through another workshop (S4 of Fig. 2). The participants gave us their feedback on the simulation process, the anticipated challenges of the plausible future landscape and the needed measures toward the sustainability of the landscape.

3. Results

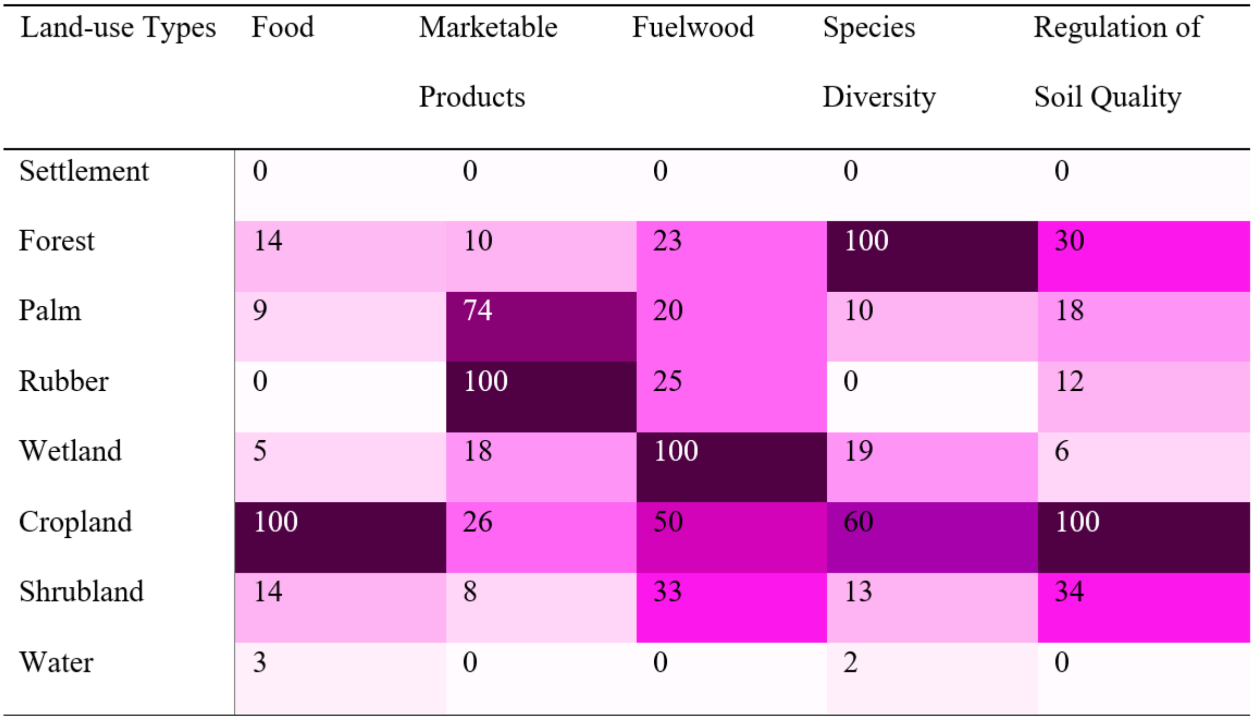
3.1 Capacity to provide ecosystem services at the landscape level

Table 3 presents the values of locally relevant ES provided by land-use types: food, marketable products, fuelwood, species diversity, and soil quality regulation. As the primary land-use type, cropland showed the highest capacity to provide food. Additionally, the land-use actors considered fruit-trees and bush meats from forest and shrubland, palm nuts and coconut fruits from palm, and marine food from wetland and water bodies to contribute to the food source; hence these land-use types were assigned values under food provisioning. Settlement and rubber showed no capacity in the provision of food. The landscape capacity in providing marketable products was mainly delivered by rubber, followed by palm (Table 3). The sale of food from cropland contributed to the landscapes' capacity to provide marketable products. The local land-use actors also considered the collection of firewood and other products (fruits, marine food, Non-timber forest products) for sale from forest products and wetlands as marketable products (Table 3). Mangroves (within wetlands) is the primary source of fuelwood for smoking fish, the chief alternative livelihood in this landscape, as perceived by the land-use actors. Cropland was also considered to provide fuelwood for household cooking through branches and stalks of trees and crops. The potential of rubber to deliver fuelwood provisioning was related to pruned branches. Similarly, the capacity of palm, shrubland, and forest to provide fuelwood was identified with the collection of deadwood and branches of trees, which are used for household energy. The land-use actors perceived the forest to provide substantial species diversity, followed by cropland. The habitat provided by mangroves for the proliferation of other species, palm intercropping with other crops, and shrubland were also considered to contribute to species richness. Settlement and rubber showed no capacity in the provision of species diversity. Lastly, cropland presented the highest level of capacity for the regulation of soil quality. The other land-cover types showed moderate levels to regulate soil quality except for settlement and waterbody.

The assessment matrix (Table 3) combined with the land-use map (Fig. 2) led to the current capacity of the study area to provide ES (Fig. 3). The ES balance tables illustrated the individual ES values corresponding to the spider chart. Marketable products exhibited the highest ES value on the study landscape, followed by soil quality regulation, while the landscapes' capacity for species diversity provision was the lowest. Food provision was the second lowest and slightly higher than species diversity provision.

Table 3: Ecosystem service assessment matrix showing the relationship between land-use types and their capacity to provide ES within a range between 0 (no capacity to provide ES, in white) and 100 (highest

capacity to provide ES, in dark purple).



Land-use Types	Food	Marketable Products	Fuelwood	Species Diversity	Regulation of Soil Quality
Settlement	0	0	0	0	0
Forest	14	10	23	100	30
Palm	9	74	20	10	18
Rubber	0	100	25	0	12
Wetland	5	18	100	19	6
Cropland	100	26	50	60	100
Shrubland	14	8	33	13	34
Water	3	0	0	2	0

3.2 Impact of land-use change scenarios on the provision of ecosystem service

The transition rule-set for simulating rubber and settlement expansion is shown in Table 4. Neighboring conditions were more emphasized as proximity effect and the geographical location of land-use/land-cover types at the landscape level. This means that depending on the geographical location of a land-use/land-cover type, either rubber expansion or settlement expansion can occur but not simultaneously. Regarding rubber expansion, the local stakeholders' perceived cropland, shrubland, and palm as the potential land-cover types to be converted to rubber with a high transition probability of approximately 85%, 90%, and 60%, respectively (Table 4). The local stakeholders perceived the neighboring condition to account for the conversion from cropland, shrubland, and palm to rubber to occur more in the landscape's western part (rural areas) and can share a border with any other land-use/land-cover type. Forest, wetland, and settlement found in the western part of the study landscape showed a lower likelihood of rubber expansion as perceived by the land-use actors. Regarding settlement expansion, the stakeholders perceived cropland, shrubland, and palm to have a transition probability to settlement of approximately 50%, 90%, and 50%, respectively. The stakeholders also perceived expansions in settlement areas to concentrate more on the study landscape's eastern part (peri-urban areas) than other areas.

3.2.1 Impact of rubber expansion

Applying the transition probability rule-set (Table 4), the conversion to rubber resulted in a negative area change in most of the land-use/land-cover types (Table 5). The analysis identified a considerable conversion to rubber in palm, shrubland, and cropland (Table 5). Iterative application of the transition rule-set resulted in the intensification of rubber expansion (the expansion of pink areas in the land-use/land-cover maps, Fig. 4), which showed more visible trade-offs between rubber and other land-use types (Table 5). However, settlement, forest, wetland, and water body were insignificantly influenced by rubber expansion (Table 5). Rubber expansion similarly decreased the ES values, especially food provision and regulation of soil quality (Fig. 4). On the other hand, marketable product was increased as a trade-off (Table 5).

Table 4
Transition probabilities (in percentage) of land-cover types and neighboring conditions according to each land-use change driver.

Land-cover change driver	Initial land-use type	Target land-use type	Transitional probability (%)	Neighboring conditions
Rubber expansion	Cropland	Rubber	85	Location of initial land-cover type in the western part of the study landscape. The proximity of the initial land-cover type to a rubber farm, cropland, shrubland, or palm. With or without one cell of rubber farm located as neighboring cells around cropland, oil palm, rubber farms, and shrubland.
	Shrubland		90	
	Palm		60	
Settlement expansion	Cropland	Settlement	50	Location of initial land-use type in the eastern part and along the 15km road stretch from Agona to Apowa of the study landscape (Fig. 6-Appendix) (Bugri & Yeboah, 2017). The proximity of the initial land-use type to the major road network. With or without one cell of settlement as neighboring cells to shrubland, cropland, or palm.
	Shrubland		90	
	Palm		50	

Table 5
Area change of land-use/land-cover types influenced by the intensification of rubber expansion

Land-use change	Land-cover type	Iteration 2 (%)	Iteration 5 (%)	Iteration 10 (%)
Rubber expansion	Settlement	0	-0.01	-0.02
	Forest	0	0	0
	Rubber	8.33	14.69	21.19
	Palm	-2.56	-4.58	-6.56
	Wetland	0	0	-0.01
	Shrubland	-1.48	-2.43	-3.23
	Cropland	-4.29	-7.66	-11.37
	Waterbody	0	0	0

3.2.2 Impact of settlement expansion

Settlement expansion resulted in a distributional change in the land-use/land-cover types (the expansion of red areas in the land-use/land-cover map, Fig. 5). Palm, shrubland, and cropland declined in area changes compared to the initial land-use types, whereas settlement only increased (Table 6). The other land-use types recorded insignificant changes in the area by all the iterations. Impacts on the landscape's capacity to provide ES under settlement expansion resulted in decreases in all the ES provided by the landscape (Fig. 5).

Table 6
Area change of land-cover types influenced by settlement expansion

Land-use change	Land-cover type	Iteration 2 (%)	Iteration 5 (%)	Iteration 10 (%)
Settlement expansion	Settlement	2.99	5.55	11.09
	Forest	0	0	0
	Rubber	0	-0.01	-0.01
	Palm	-0.15	-0.46	-2.33
	Wetland	0	0	0
	Shrubland	-2.39	-3.79	-5.71
	Cropland	-0.45	-1.26	-3.02
	Waterbody	0	0	0

3.3 Land-use actors perceived challenges of the 'BAU' scenario

Regarding the tested scenarios, the local stakeholders who participated in the workshop shared their perceptions on social, economic, and environmental threats potentially led by the plausible future landscape scenario. These included food shortage and reliance on the market for food supply, a change in cultural/traditional values, land degradation due to rubber expansion, species habitat degradation, ecosystem degradation, and reduction in species diversity (Table 7). One participant (farmer) mentioned

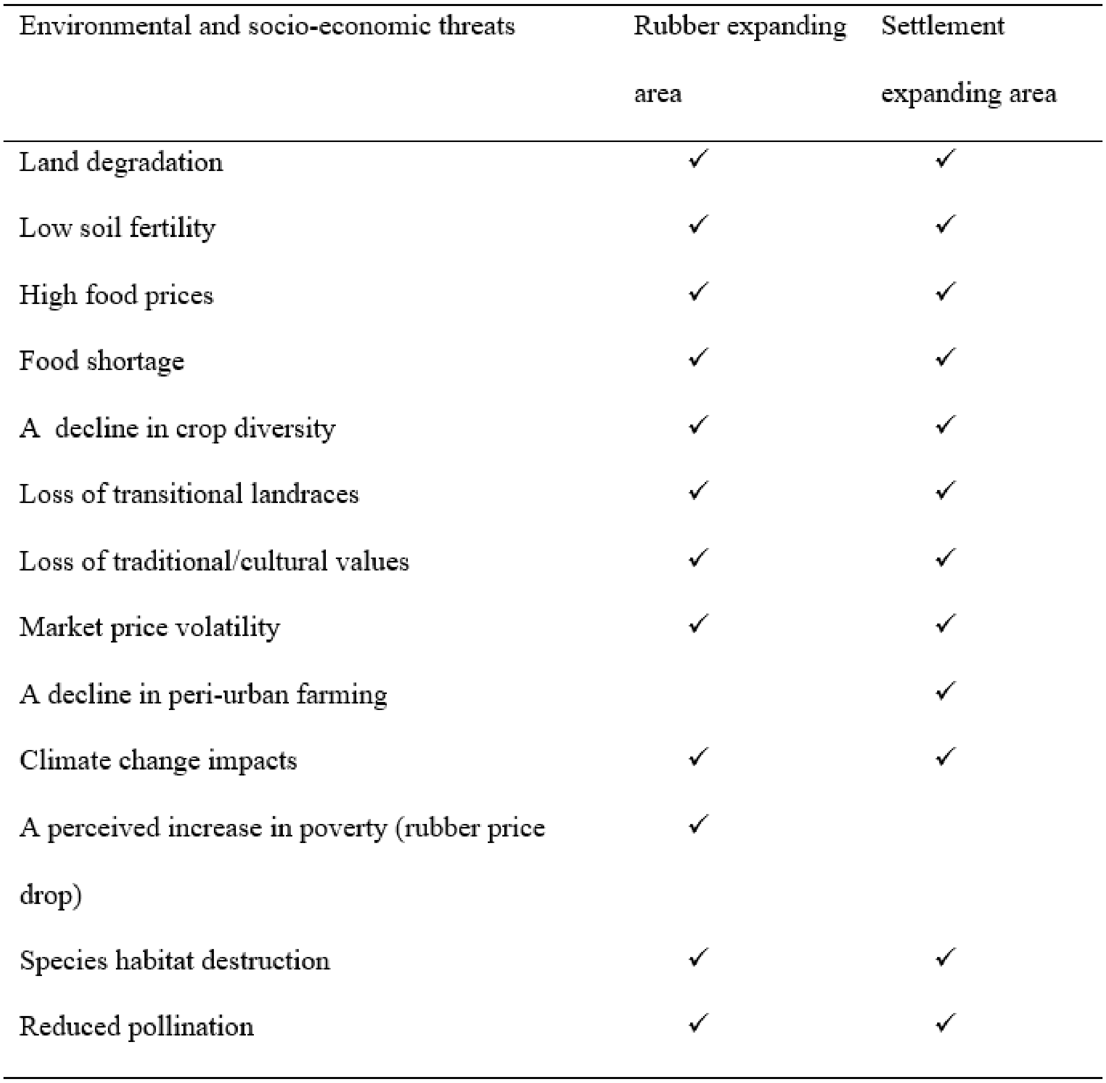
'Today, during farmers' day celebration, the different types of crops displayed have reduced dramatically compared to about ten years ago. We used to have traditionally grown vegetables and crops, but in recent times, we no longer have them.'

One participant from the institutional sector lamented the likely decline in rubber prices and its consequence on local farmers' livelihoods and economic life. The local farmers were alarmed by the implications of the possible market decline in rubber prices. One participant (rubber farmer) expressed his fears

'When rubber prices drop, we can not sell the latex from our rubber farms. This means our land will be locked, and there will be no money from the sale of rubber and no land for food production. We, therefore, cannot purchase adequate food from the market for our household'.

Participants from the spatial planning unit drew attention to settlement-expanding areas and the likely threat of food price volatility and competition with the oil industry for food items. In addition, peri-urban farming decline and land scarcity were perceived as additional challenges under the 'BAU' scenario.

Table 7: Participants' perceptions of challenges on the landscape under the 'BAU' scenario



Environmental and socio-economic threats	Rubber expanding area	Settlement expanding area
Land degradation	✓	✓
Low soil fertility	✓	✓
High food prices	✓	✓
Food shortage	✓	✓
A decline in crop diversity	✓	✓
Loss of transitional landraces	✓	✓
Loss of traditional/cultural values	✓	✓
Market price volatility	✓	✓
A decline in peri-urban farming		✓
Climate change impacts	✓	✓
A perceived increase in poverty (rubber price drop)	✓	
Species habitat destruction	✓	✓
Reduced pollination	✓	✓

3.4 Perceived measures towards sustainable landscape development

The participants perceived the following three actions as key to ensuring transformation in land-use activities and sustainable landscape development. First, the participants anticipated the 'BAU' scenario would have implications for their livelihoods and environment and advocated sensitization among the various land users. The participants believed that enhancing awareness of the dangers associated with the plausible future landscape can instigate behavioral change among the multiple land users and might contribute to the sustainable development of the study landscape. Secondly, the participants advocated for the participatory development of alternative site-specific land-use scenarios that address sustainability. The participants shared concerns about the inclusive collaboration of all actors in the participatory design of alternative sustainable land-use scenarios. Lastly, participants perceived that designing policies backed by laws to govern the implementation of alternative land-use scenarios will be vital in achieving landscape sustainability.

4. Discussions

4.1 Local perceptions of ecosystem services provisioning and landscape change

The participants perceived food, fuelwood, marketable products, soil quality regulation, and species diversity as the most locally relevant ES on the study landscape (Table 2). The identified ES is a typical characteristic of smallholder landscapes in SSA and have been noted to serve as the pivot to human well-being, serving as poverty alleviation, climate mitigation, and economic resilience, delivering various goods and services such as food, water, biological diversity conservation, and soil quality regulation (Milder et al., 2014). The AWMA (2018) describes the study landscape as largely rural, with about 66% of the population dependent on smallholder agriculture. The agricultural activities and nature-dependency may explain this perception by the participants with the choice of ES on the study landscape.

Furthermore, we observed that the participants regarded cropland to provide the highest form of food compared to the other land-cover types (Table 3). Smallholder farming in SSA mainly produces food for household consumption (Chikowo et al., 2014) and may explain the participants' perception of cropland providing the highest form of food. However, participants viewed rubber and palm as contributing to marketable product provisioning more than the other land-cover types (Table 3). The recent shift in crop choices to rubber and palm shifts the subsistence needs of cropland to commercial purposes. This may account for the participants' perception of rubber and palm as the highest and second-highest land-cover types to provide marketable products on the study landscape. The perception that wetland, including mangrove, provides the highest fuelwood can be backed by the particular demand of mangroves for smoking fish, a popular alternative livelihood on the study landscape (Nunoo & Agyekumhene, 2022). Mangrove is perceived to infuse an exceptional taste into smoked fish attracting higher prices on the market (Jones et al., 2016).

Estimating species diversity, a count of species richness, abundance, and distribution, was relatively higher in the forest than in the other land-cover types (Table 3). Participants agreed with the estimated indicator value for the forest, and explained that the forest is not accessible by the public; hence human interference is largely reduced. According to the forest and wildlife report of the Cape Three Points Forest Reserve, the recent ecosystem survey also recorded 17 species of medium and large mammals, 27 tree species, and 45 species of butterflies (Hen Mpoano, 2019). In addition, Ghana's forest reserves and national parks cannot be used for agricultural purposes due to regulation laws for their establishment and management. For example, Forest Protection (Amendment 2002) Act 624 and the Forest Act 1927 (CAP 157) prohibit agricultural activities in forests. Strong regulations and actions may have contributed to assuming forests as the highest land-use type to provide species diversity. The cropping system practiced on the study landscape (mainly main crop intercropped with other minor crops) may also explain cropland accounting for the second highest land-use type in species diversity provision. Farming in the southern part of Ghana is more heterogenous and favored by the bimodal rainfall pattern compared to the unimodal rainfall pattern and monocropping system in the northern parts of Ghana (Bellon et al., 2020; Kuivanen et al., 2016). The integration of diverse crop species as mixed-cropping in the southern part of Ghana facilitates the resilience of farming and cushions farmers during periods of environmental shocks (Asfaw et al., 2019; Bellon et al., 2020).

Additionally, soil quality regulation, measured by litterfall and decomposition rate, was highest in cropland (Table 3). The experts in the Delphi method attributed the seasonal and perennial cropping system and land preparation methods (thus leaving harvested debris on the ground to rot and mixed with the soil, a technique locally known as *proka*) to facilitate high litter production and decomposition in cropland. Cropland/agricultural lands are also mentioned in other studies to contribute to soil quality regulation in the context of SAA (e.g., Drechsel & Dongus, 2010; Fenta et al., 2020).

Interestingly, the study found that the participants' perceptions coincided with the land-cover/land-use map produced from GIS and remote sensing methodologies of Asante Yeboah et al. (2022) regarding landscape change under rubber and settlement expansion. The participants perceived rubber to dominate the western part of the study landscape, and they expected any other land-cover shift to rubber to occur in this region. On the contrary, the participants expressed any expansions in settlement to occur in the eastern part of the study landscape and along the road stretch between Agona Nkwanta and Apowa (Fig. 6-Appendix). This perception does not differ from the satellite-based land-cover maps of the study landscape, which show in 34 years, rubber expanded more than three times its initial size. It dominated the western part of the study landscape, while settlement grew more than four times its initial size and dominated the eastern part (Asante-Yeboah et al., 2022). The participants perceived that the availability of farmlands and the willingness of farmers/landowners in the western part of the study landscape would influence the preference for rubber rather than any other land-cover type. The participants also mentioned the lower economic returns from food-crop farming compared to the higher financial returns from rubber plantation to influence farmers' shift from cropland to rubber plantation. Such perceptions of the local stakeholders concur with the findings of Bugri & Yeboah (2017). Other factors, like the customary ownership of land in rural areas compared to the statutory right of land in the municipal regions of Ghana, may account for the easy conversion of farm and fallow lands into rubber cultivation (Kasanga & Kotey, 2001). This may further explain the participants' perceptions of rubber expansion dominating the western part of the study landscape.

Regarding the eastern part of the study landscape, the participants also perceived the influence of oil discovery and economic activities in the neighboring city, Sekendi-Takoradi, to persuade landowners to release lands for infrastructural purposes. In addition, the road network, accessibility, and improved infrastructure facilitate the 'hot spot' expansion in settlement along the 15km road stretch from Agona Nkwanta to Apowa (Fig. 6-Appendix). The influx of migrants and the presence of international oil companies in Sekendi-Takoradi, well-known as the oil city of Ghana, are driving investments in commercial development and real estate in this region (Fiave, 2017). The oil city is expanding horizontally toward outlying towns according to the infrastructural development and building construction, contributing to settlement expansions in the eastern part of the study landscape (Mensah et al., 2018; Obeng-Odoom, 2014). Surprisingly, the participants perceived no environmental conditions to influence the land-use/land-cover changes to either rubber or settlement. For example, rubber establishment requires a slope of less than 20% (*Personal communication, GREL, AWMA*); however, the study landscape falls below this slope category; hence converting land into rubber is not hindered by environmental attributes. Structural plans prepared for the study landscape broadly categorize about 50% of the eastern part of the landscape as suitable for infrastructure; hence, environmental attributes did not significantly affect the land-cover change (*Personal communication, Physical Planning Unit, AWMA*).

4.2 Strengths and weaknesses of the methodology

This study emphasizes using land-use actors' perceptions in a modeling framework to generate site-specific spatially explicit information that are vital policy considerations for the conservation and sustainable use of natural resources and ecosystems (Beck et al., 2014). The participatory approach adopted in this study to assess and interpret the relationship between land-use types and their capacity to provide ES differs from the scientifically oriented viewpoint as applied in other studies (Anderson et al., 2017; Arowolo et al., 2018; Leh et al., 2013; Vrebos et al., 2015). In this participatory approach, we identified the locally specific challenges that may associate with future landscape change and the possible measures to ensure the sustainability of the landscape. The participatory approach and inclusion of local perceptions allow for reflecting the local people's experience, which has evolved through trial and error and has proven flexible enough to cope with change (Feurer et al., 2019; Olsson & Folke, 2001). Such local knowledge complements existing scientific-based findings (e.g.,Kettle et al., 2014; Klenk et al., 2017; Posner et al., 2016). The participatory approach also strengthens the unraveling of the local ES provided by the land-cover types. In so doing, we could capture each land-cover type's multiple benefits. For example, in the identification of food provision, the study captured all parts of a land-use type used as food for household consumption. The approach allowed expressing indicator values in percentage rather than limiting food provisioning to only yield per hectare as used in other ES studies (e.g.,Dunford et al., 2015; Karimi & Taifur, 2013; Koschke et al., 2012; Palacios-Agundez et al., 2015). Using yield per ha only assumes a single ES is derived from a land-cover type (e.g, woodlot only provides fuelwood, cropland only provides food, and monocropping farms only provide marketable products) (Li et al., 2017). In addition, using the participatory approach, we could eliminate double counting, such as valuing fuelwood for household consumption and as a marketable product concurrently (Koo et al., 2019). The participatory approach involving farmers in land-use governance and their views about the future increases local negotiation power in decision-making (Asubonteng et al., 2021).

On the contrary, the approach exhibited some weaknesses that allowed the exclusion of some significant ES. For example, ES, such as pollination, carbon sequestration, flood control, and aesthetic beauty, are prominent ES in the study landscape. However, indicators to assess those ES are challenging to be identified due to the stakeholders' difficulties in understanding the capacity of different land-use types to provide such intangible ES (Koo et al., 2019). A stakeholder opinion-oriented approach limits the inclusion of ES that are difficult to assess by land-use actor perceptions. Time limitation, cost, and lack of experts also restricted obtaining ES indicator values/proxies for these ES using other sources (e.g., field data collection for carbon sequestration estimation, expert judgment for pollination potential, and flood regulation). Therefore, the study could only include soil quality regulation where experts could provide proxies.

4.4 Implications of land-use change on landscape and ecosystem service provision

The study focused on two drivers of land-use change, rubber and settlement expansion, and created a plausible future landscape base on the 'BAU' scenario. We chose these two for three reasons. First, the land-use/land-cover map of Asante et al. (2022) shows higher rubber and settlement expansion rates than other land-cover types on the study landscape. Second, the land-use actors recognize rubber and settlement expansion as the most significant drivers of land-use change on the study landscape. Third, the prevailing market conditions underlying rubber and settlement expansions facilitate its continual expansion. The result from the participatory scenario building and spatially explicit simulation indicates risk in the sustainability and management of the landscape. For instance, in the eastern part of the study landscape, where settlement is expanding, the population is primarily characterized by skilled workers having access to various employment opportunities and diversified income (Ablo, 2018; Fiave, 2017; Otchere-Darko & Ovadia, 2020). However, most people residing in the western part of the study landscape are unskilled workers (Otchere-Darko & Ovadia, 2020). Their livelihoods depend mainly on subsistence farming. The diversified cropping system in southern Ghana offers several benefits to farmers under risk-copping strategies and poorly functional markets. For example, diversified cropping systems produce varieties in products for diversified purposes (Keleman et al., 2013), reduce farmers' vulnerability to market and climate variability (McCord et al., 2015), and positively contribute to household dietary diversity and cultural significance (Hoffmann & Gatobu, 2014). From the participant's perceptions, the disappearance of cropping diversity with the replacement of rubber and settlement will result in the erosion of the multifunctional capacity of the landscape.

The result indicates urgent actions for a balanced and sustainable ES provision on the study landscape. A close partnership among rubber-producing firms, settlement expansion firms, landowners, donors, the government, and the scientific/research body must be deepened to explore land-use options that address the landscape's ecological, social, and economic threats. The few remaining open spaces, cropland, home gardens, and peri-urban farms are the pivot for the diverse needs of the local people in food access and sovereignty, outdoor activities, and recreation and need to be managed sustainably

5. Conclusion

The participatory scenario building and spatially explicit simulation approach applied in this study to answer four research questions of; i) How do the land-use actors perceive the current landscape to provide locally relevant ES?, ii) How do land-use actors perceive a future landscape to provide ES under a business-as-usual 'BAU' scenario? iii) What challenges do the land-use actors perceive in the capacity of ES provisioning under the 'BAU' scenario? and v) What appropriate actions are needed for sustainable landscape development?, successfully identified land-use actors' perception on land-use change, trade-offs in ES, challenges associated with altered landscape, and measures to ensure the sustainability of the landscape. The approach offers feasibility in integrating land-use actors' perceptions and opinions in landscape decision-making to ensure land-use planning policies' acceptability and feasible implementation. However, facilitators are cautioned in managing participants' expectations and not making promises that are not feasible to avoid disappointments and prevent participants from withdrawing from engaging in future-related processes under integrated landscape approaches. In this paper, the authors acknowledge the findings as a plausible future state and advocate that landscape sustainability policies incorporate the rich and diversified knowledge embedded in land-use actors to uncover hidden context-specific knowledge desired for landscape sustainability.

Declarations

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Competing Interests

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Compliance with Ethical Standards

Conflict of interest: The authors declare no conflict of interest

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Figures

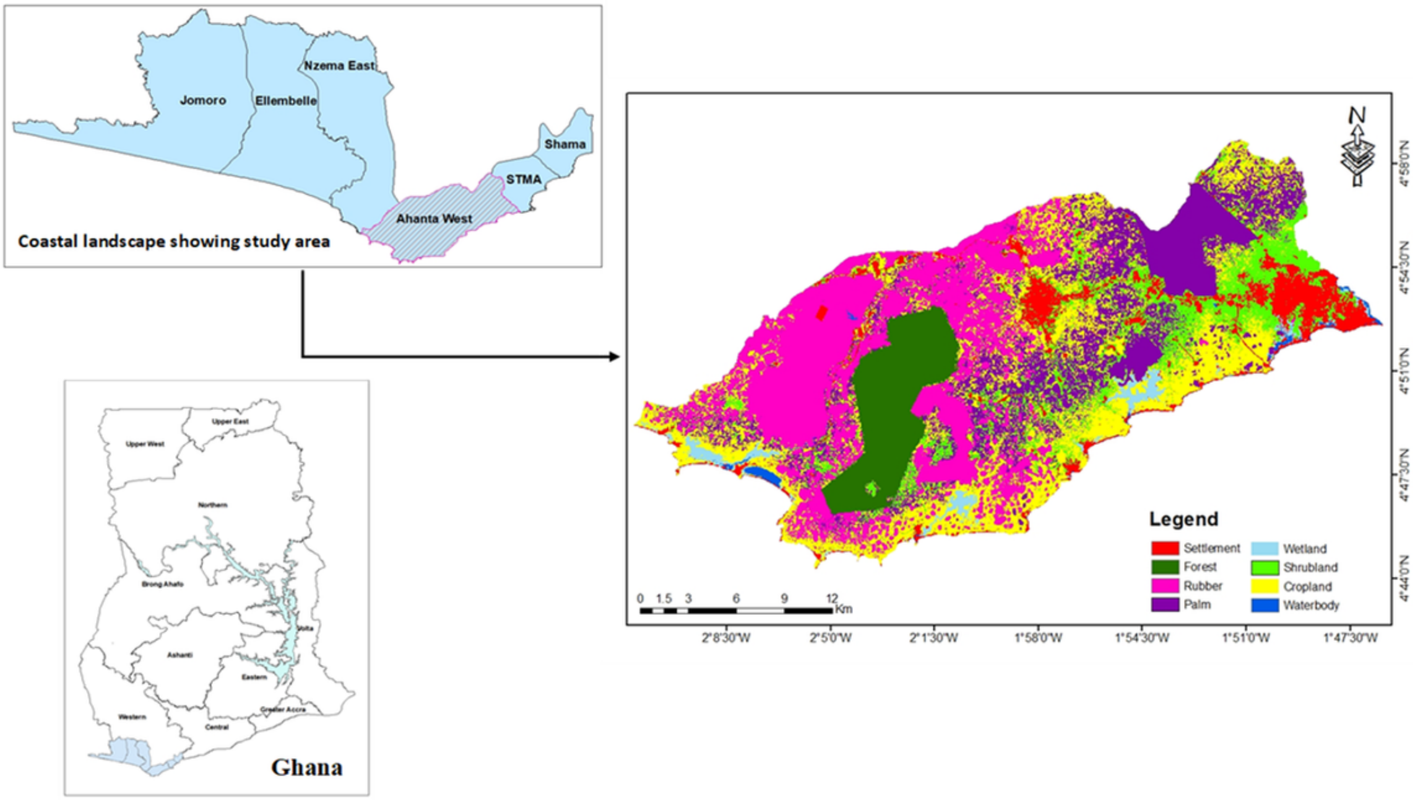


Figure 1

Location and land-use patterns of Ahanta West Municipal Assembly in southwestern Ghana

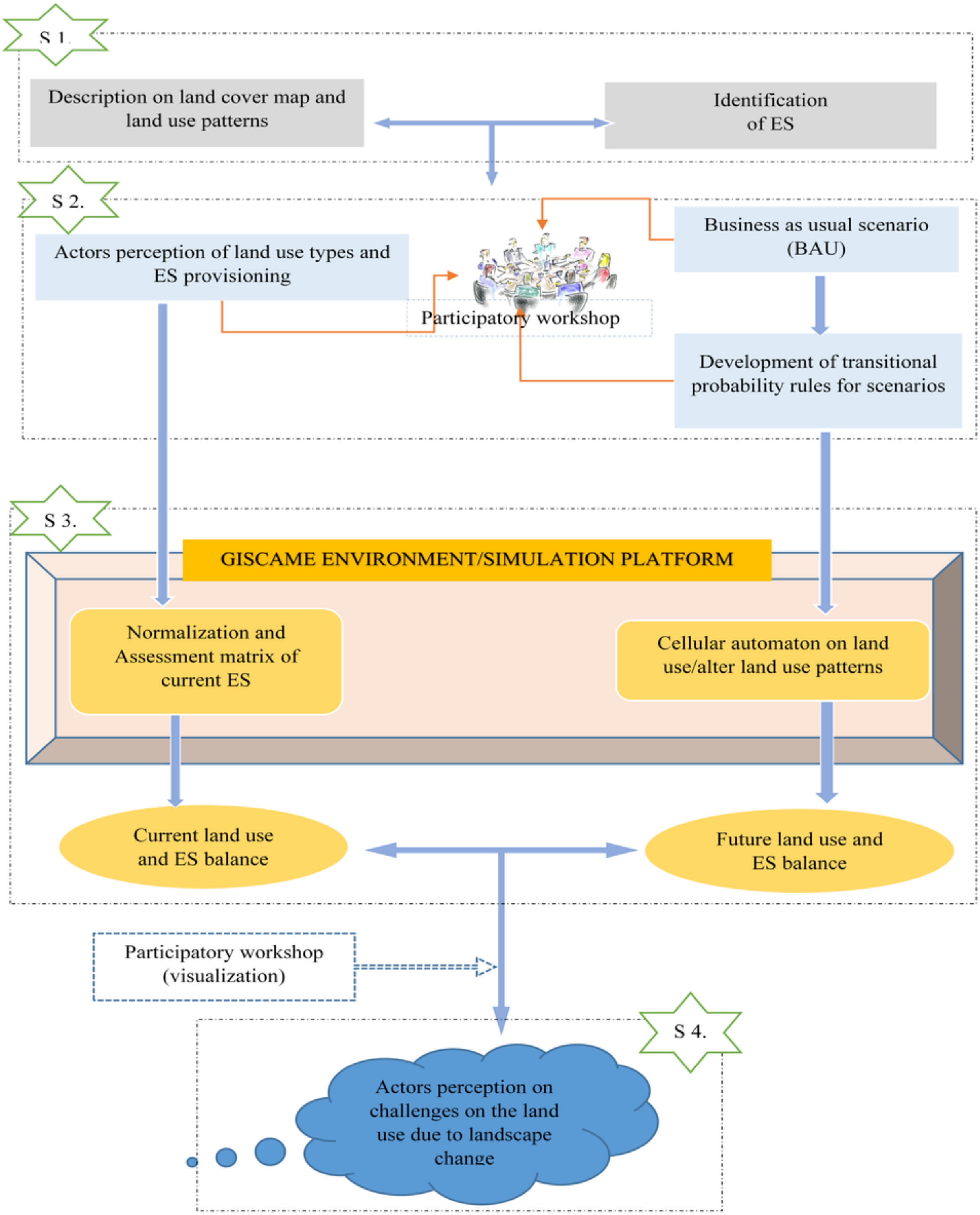
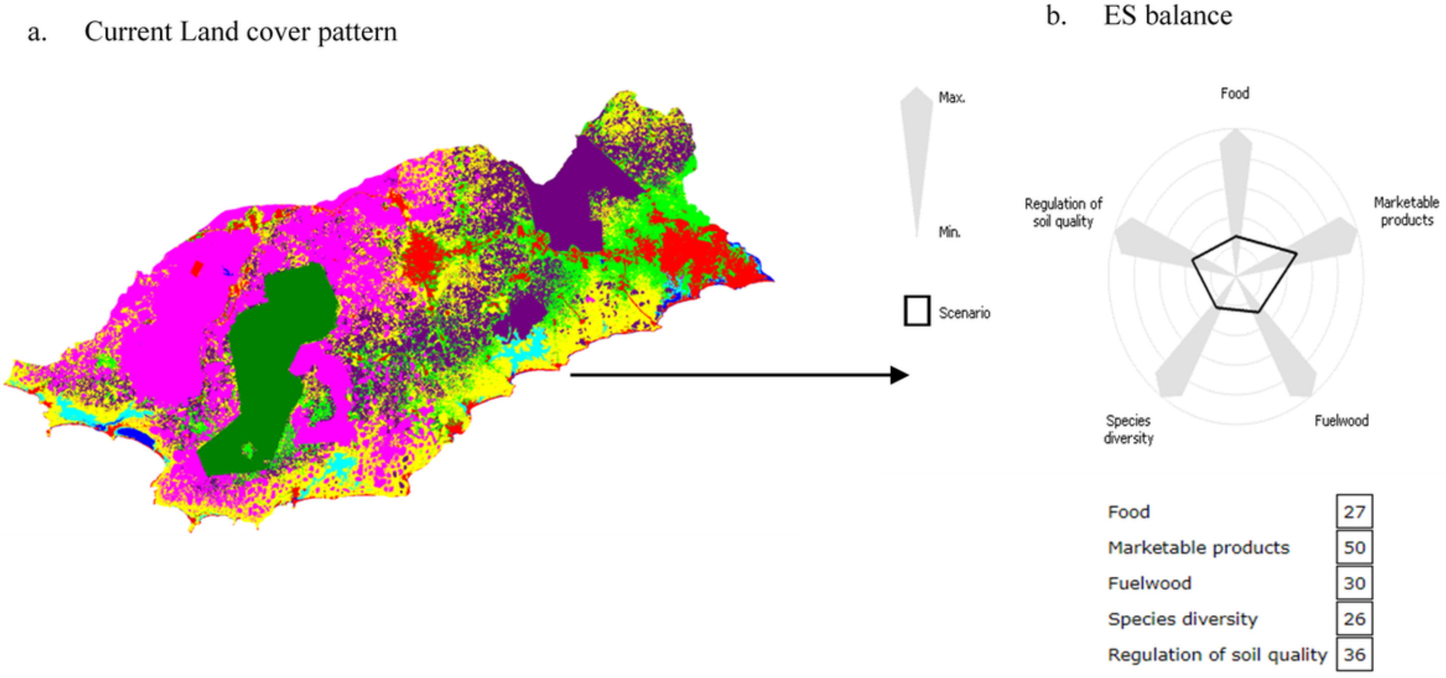


Figure 2

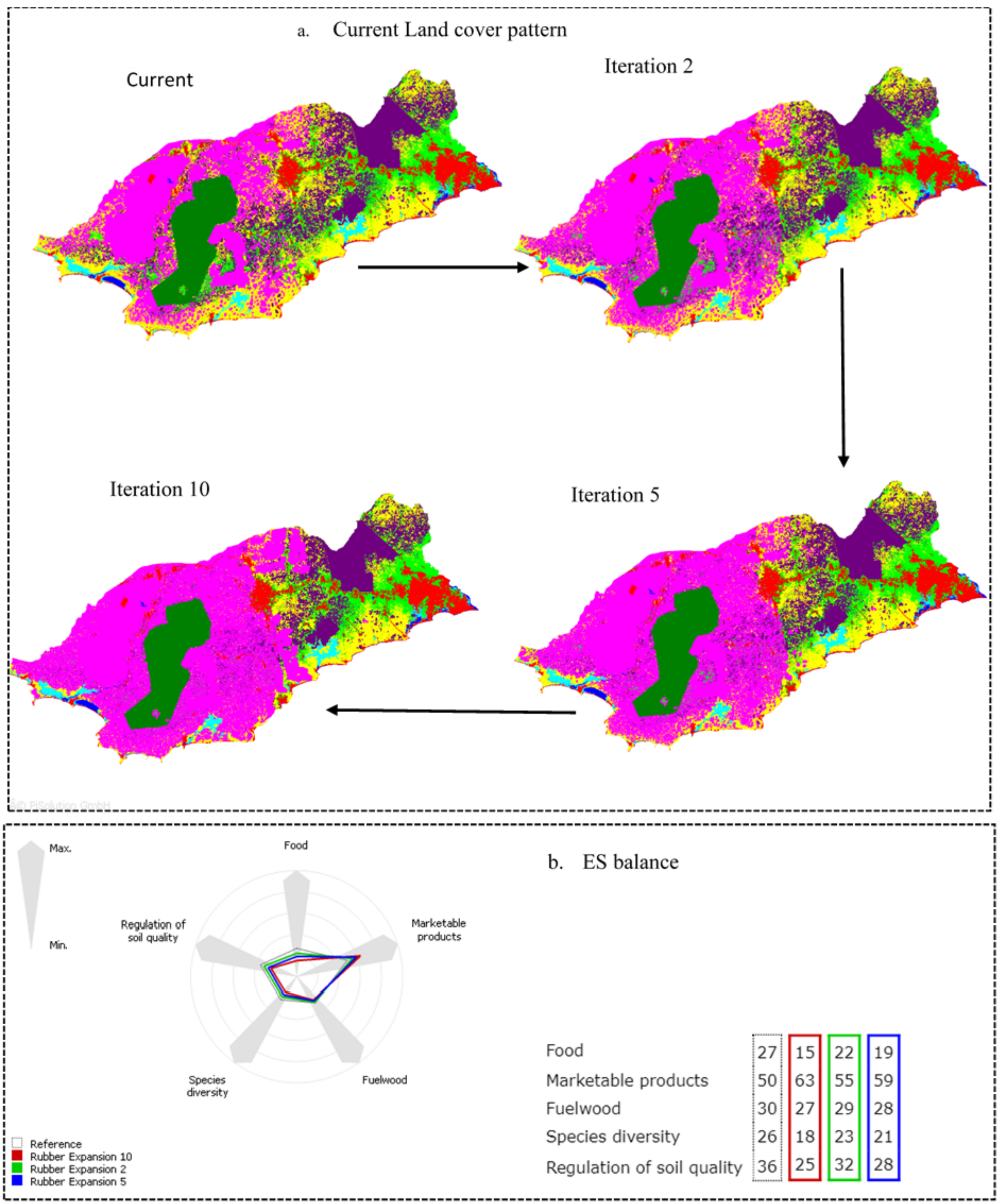
Description of the methodological framework applied in the study



Food	27
Marketable products	50
Fuelwood	30
Species diversity	26
Regulation of soil quality	36

Figure 3

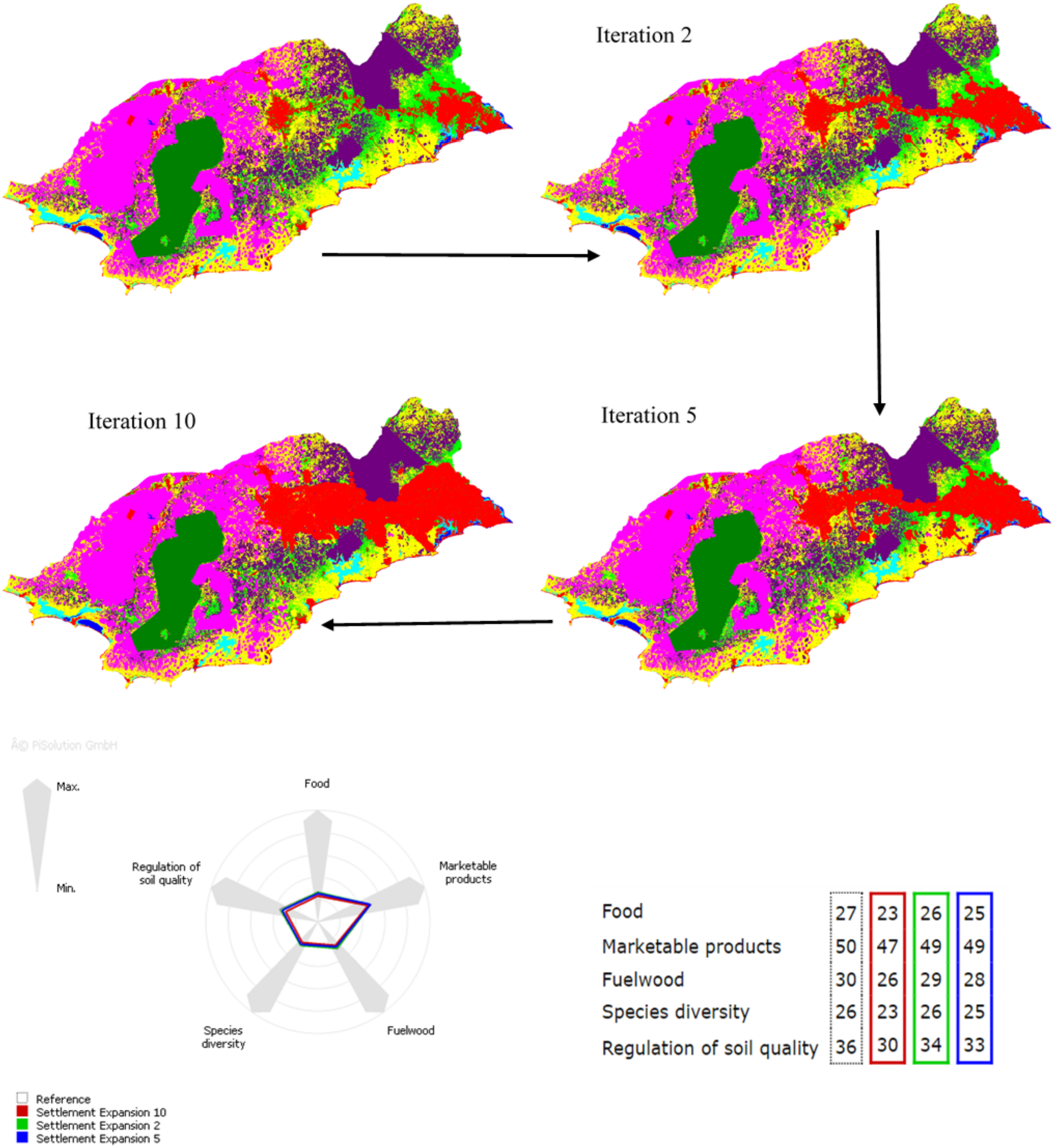
Ecosystem service values at the landscape level: a. current land-use pattern, b. ecosystem service status provided by the current land-use pattern in the balance table corresponding with the spider chart.



Food	27	15	22	19
Marketable products	50	63	55	59
Fuelwood	30	27	29	28
Species diversity	26	18	23	21
Regulation of soil quality	36	25	32	28

Figure 4

Impact of rubber expansion on land-use pattern and ecosystem service provisioning in the study region. The spider chart displays the change from the current ecosystem services provisioning level (grey color line) to a future state by intensifying rubber cultivation. The green line means a two-time iteration simulation (Rubber expansion 2) which equals ten years, as agreed with the participants. The blue line means a five-time iteration simulation (Rubber expansion 5) which equals 25 years, as agreed with the participants. The red line denotes a ten-time iteration simulation (Rubber expansion 10) which equals 50 years, as agreed with the participants. The table on the right side corresponds to the spider chart, which indicates the landscape capacity of ecosystem service provisioning.



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Food	27	23	26	25
Marketable products	50	47	49	49
Fuelwood	30	26	29	28
Species diversity	26	23	26	25
Regulation of soil quality	36	30	34	33

Figure 5

Impact of settlement expansion on land-use pattern and ecosystem service provisioning in the study region. The spider chart displays the change from the current ecosystem services provisioning level (grey color line) to a future state as settlement expands. As agreed with the participants, a two-time iteration simulation (Settlement expansion 2) equals ten years (green line). The blue line means a five-time iteration simulation (Settlement expansion 5) equals 25 years. Rubber expansion 10 equals 50 years and is denoted by red lines. The table accompanying the spider chart indicates the landscape capacity of ecosystem service provisioning.

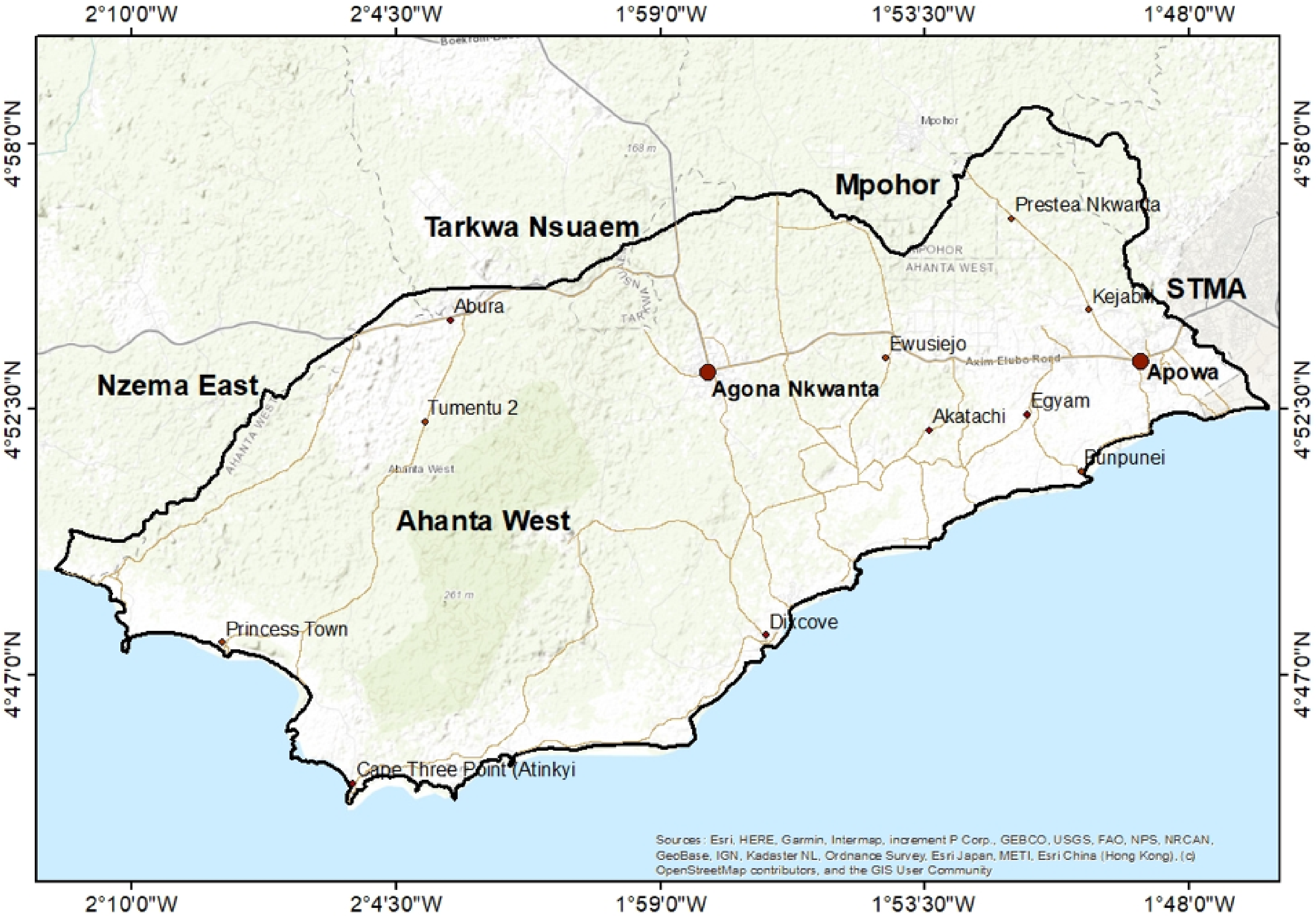

Figure 6

Map of Ahanta West Municipal Assembly (AWMA) showing the location of Agona Nkwanta to Apowa, and the Sekendi Takoradi Municipal Assembly (STMA).

Supplementary Files

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- Appendices.docx

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