Expanding tree-crop farming

An integrated socio-spatial analysis in a transitioning mosaic landscape in Ghana

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Chapter Six

6. Synthesis and conclusions

6.1 Introduction

Thanks to their diversity and structural complexity, mosaic landscapes are multifunctional and meet the needs of diverse actor groups at multiple scales. At the landscape level, they are the basis for food security, livelihoods, and general wellbeing. However, there is persistent competition between societal socio-economic needs and conservation and climate mitigation goals. As a result, stakeholders' interests – originating from multiple scales – are diverse, sometimes complementary and sometimes conflicting, resulting in synergies and trade-offs between land uses.

Despite the increasing recognition of these trade-offs and associated loss of landscape services (Grass et al., 2020; Macchi et al., 2020; Sunderland et al., 2007), forest frontier landscapes in the tropics are threatened by the expanding establishment of tree crops such as cocoa and oil palm (also referred to as commodity crops, cash crops or, in the case of, for instance, *Jatropha* spp., energy crops). Usually driven by market demands, the choice to expand tree crops is backed by national policies motivated by economic benefits, job creation and improved incomes at the landscape and national level. As a result, mosaic landscapes are rapidly transforming due to the loss of indigenous land-use systems and now featuring growing dominance of commodity crop cultivation. Meanwhile, international organisations concerned with biodiversity conservation and landscape management have cautioned against the continuous decline in native ecosystems and their concomitant disruption in providing 'nature's contribution to peoples wellbeing' to local communities (IPBES, 2019). The expansion of commodity crops occurred in a spatially and socioeconomically uncoordinated manner and has not yielded inclusive outcomes. From a spatial perspective, development pathways that aim to reconcile societal, development, and ecological needs require insights into the interactions between commodity crops and other ecosystems, their consequences, and landscape-level priorities across different actors (Sayer et al., 2013). Yet, information on the dynamics in these spatial relationships is hardly integrated and available at landscape levels.

Against this background, this study posed the research question: How does the expansion of tree crops affect the structure and multifunctionality of mosaic landscapes, and how do actors perceive the dynamics and effects and develop strategies to address them?

This question was unpacked into the following four sub-questions that focus on biophysical and social-ecological changes in a transitioning landscape in the Eastern Region of Ghana where smallholder production of cocoa and oil palm has expanded significantly over the past three decades:

The biophysical aspects were examined through the questions: i) how did the expansion of tree crops affect the composition and land-cover transitions in a mosaic landscape between 1986 and 2015, and ii) how did tree-crop expansion affect the configuration of mosaic landscapes? The socio-ecological dimension was addressed by the questions: iii) how do actors use landscape services and respond to trade-offs in landscape services due to changes in landscape structure, and iv) how do landscape actors perceive the effects of the expansive nature of tree-crop production and ways to address the adverse effects on people's wellbeing?

Inspired by the literature on spatio-temporal dynamics in landscapes (Brandt, 2003; Lamy et al., 2016; Sayer et al., 2013; Termorshuizen and Opdam, 2009; van Noordwijk et al., 2012), the study is conceptually anchored in integration-segregation theory, the land sharing and land sparing debate, integrated landscape approaches, and landscape services. The conceptual framework (Figure 1.4) illustrates that changes in the composition of a landscape potentially lead to changes in the structural configuration (the first question, addressed in Chapter 2), which either results in a shift from integration towards segregation or the reverse (the second question, addressed in Chapter 3) with countless variations in between. Structural changes have implications for the provision of and people's use of landscape services (the third question, addressed in Chapter 4). Given the dynamics in landscape structure and services as well as the varying availability of substitutes, people's perceptions of landscape trajectories and desires to compensate for the losses and enhance benefits will influence their vision for future pathways (the fourth question, addressed in Chapter 5).

The study employed a set of mixed methods that combined quantitative, qualitative, and spatial data collection and analytical approaches in the investigation. For the analysis of landscape composition and transitions (Chapter 2) and structural dynamics (Chapter 3), the study employed image classification, change detention and transition intensity analysis, and landscape fragment statistics, respectively. A household survey, informal interviews, and field observations were used to investigate temporal patterns in landscape services use and response strategies (Chapter 4). Forecasting, integrated backcasting, and participatory mapping methods were employed to unravel actors' desired future landscape (Chapter 5). This integration of methods allowed for the triangulation of research findings and enabled linking social-ecological and biophysical dimensions of landscape change.

The empirical chapters (2 to 5), which address the sub-questions, have been published as independent research articles. However, as outlined in the conceptual framework (Chapter 1), they are interlinked and complementary in providing a holistic understanding of the mosaic landscape's structural dynamics and social processes over time. The following section (6.2) recaps and synthesises the empirical findings regarding each research question, ending with a discussion of the main research question. Next, this chapter highlights the theoretical and methodological contributions of the study (Section 6.3) and reflects on the methodology (Section 6.4) and limitations of the research (Section 6.5). Finally, the chapter concludes with suggestions for future research and policy recommendations (Section 6.6).

6.2 Synthesis of the empirical findings

6.2.1 Landscape compositional dynamics and transitions in mosaic landscapes

Chapter 2 addressed the first question: How did tree-crop expansion affect the composition of mosaic landscapes between 1986 and 2015? It assessed changes in land-cover types and their transitioning properties, including net area change, swaps, and intensities. The study landscape consisted of built-up/bare areas, food crops, cocoa, oil palm, other tree crops (notably citrus), forest, food crops, settlement, and water in 1986. A comparison of land-cover maps from 1989 and 2015 revealed, first, that land-cover categories had remained the same, but that their relative areal proportions had changed in favour of the tree crops cocoa and oil palm at the cost of forest and food-crop land. Second, the analysis showed that the annual change in oil palm outpaced the change in forest, food-crop, and cocoa areas. Third, the landscape was very dynamic, as shown by the large cocoa, food-crop, and oil palm areas that were part of the changes and location swaps. Fourth, category level intensity analysis revealed that cocoa and oil palm actively gained land areas from other land categories but were dormant losers. This means that while lands accruing to cocoa and oil palm were more than the average gains in the landscape, their losses were less than the average landscape losses. Fifth, transition-level analysis showed systematic exchanges between cocoa and food crops for which they intensively target each other for expansion. Cocoa and oil palm systematically target each other intensively for expansion. Oil palm and cocoa mainly target food-crop areas for their expansion, contributing to the scarcity of land for food-crop production (Chapter 4) and high food prices (Chapter 5). The expansion of all tree crops avoided forest areas in the landscape because most lands under forest are isolated under state protection in forest reserves (Chapter 3). Sixth, landscape dwellers associate tree-crop expansion and landscape homogenisation with economic benefits and adverse effects on biodiversity and the provision of other ecosystem services (Chapter 4 and Chapter 5). In summary, the expansion of cocoa and oil palm has caused dynamic changes in the study landscape, mainly at the cost of food-crop land and forest, especially patches outside forest reserves. It led to an increasing homogenisation of the landscape but left the main forest area intact thanks to its protected status.

6.2.2 Configuration dynamics and transitions in mosaic landscapes

Chapter 3 investigated the dynamics in landscape structural properties, addressing the questions of how composition and configuration change due to the expansion of tree crops (cocoa and oil palm) and how this affects the degree of integration or segregation in a landscape. It developed a measure, namely the landscape structural state index, which positions a landscape on an integration-segregation continuum to support landscape monitoring. The analysis showed that changes in the landscape are not restricted to land-cover proportions (Chapter 2). Several other structural properties characterise a landscape, such as diversity, fragmentation, connectivity, and naturalness. These dimensions are often overlooked in discussions and policies on expanding commodity crops in landscapes. Structurally, the diversity of the landscape remained largely stable, but land proportions under each land-cover type changed due to land transitions (Chapter 2). Confirming the findings in Chapter 2, cocoa and oil palm areas significantly expanded during the 29 years under examination. Chapter 3 furthermore revealed a reduction in patch numbers and higher aggregation of patches. In contrast, forest and food-crop areas dwindled in size and patch number. Connectivity between adjoining patches increased for all land-cover types except food-crop land, which showed a high level of interspersion and juxtaposition with cocoa, oil palm, and built-up areas (Chapter 3). The configuration of land-cover types transformed the landscape from a mosaic one to one characterised by a large forest block (in a protected area), cocoa, and oil palm interspersed with patches of food-crop land (Chapter 2). Landscape actors perceived similar changes in the configuration of the landscape (Chapter 5). Although the landscape remained smallholder-dominated by ownership, it exhibits structural characteristics similar to that of industrial plantations due to the aggregation of farm plots.

The developed index indicated that the landscape shifted towards increasing segregation by 2015 (Chapter 3). This aligns with actors' perceptions of landscape in 2018 (Chapter 5). According to actors, landscape simplification and homogenisation have adverse implications for food security, biodiversity, and landscape services (Chapters 4 and 5).

6.2.3 Changing patterns in the sources and use of landscape services and actors' response strategies

Chapter 4 examined actors' use and response to trade-offs in landscape services due to changes in landscape structure. Specifically, it addressed the following questions (i) how actors' use and sources of landscape services has changed in the past 20 years; (ii) how socio-demographic factors and production systems influence inhabitants' response strategies to trade-offs in sources and availability of landscape services; and (iii) how users' perceived degrees of substitutability of landscape services influence their response strategies. It revealed that the dominance of cocoa and oil palm in the landscape increases the supply of cash crops but generates trade-offs with other landscape services, which has implications for people's use. The use of landscape services declined except for food crops and water for domestic use (due to their relevance to wellbeing) and commodity crops (for their high economic value). The observed decline is attributed to the reduced capacity of natural sources to supply sufficient quantities to meet the demand for timber, fish, firewood, and non-timber forest products. The latter support livelihoods and wellbeing and include mortar and pestle, medicinal plants, wild fruits, bushmeat, snails, and mushrooms. Actors perceive the loss of natural sources to cocoa and oil palm as the underlying factor contributing to the declined availability and use of landscape services. In all cases, users made up for the deficit in landscape services by turning to other land-cover types or markets or substituting them with domesticated, technological, or synthetic alternatives. Factors significantly influencing strategies for acquiring food crops, fish, timber, water for domestic use and agriculture, and non-timber forest products include the dominant tree-crop area and respondents' age and occupation. The dominant tree-crop area and occupation (type of agricultural production one is engaged in) determine the availability of alternative sources. Age influences the actor's capability to move to distant areas for the collection of landscape services. Perceptions of the degree of substitutability also affected response strategies to changing availability of food, water for domestic use, mortar and pestle, wild fruits, firewood, and bushmeat if they are believed to be relatively essential, affordable, and easily accessible. Users of landscape services believe that substituting is sufficient a solution, which explains that actors' vision of the future landscape does not differ much from the status quo (Chapter 5).

6.2.4 Landscape futures in the eyes of actors and the pathway towards desired futures

Lastly, Chapter 5 addressed how landscape actors perceive the effects of the expansive nature of tree-crop production and how they want their landscape to change in the future. This study investigated landscape actors' perceptions of landscape composition and configuration in 2018 and anticipated landscape futures in 30 years under business-as-usual and desired scenarios and the actions required to realise the desired landscape future. It presented and utilised a participatory methodological framework that employs visualisation, forecasting and backcasting to facilitate actor engagement in thinking about the current and future states of the landscape under different scenarios and the implications thereof. The analysis revealed farmers' and institutional actors' awareness of landscape composition and configuration, plausible changes in the future, and the implications for landscape services.

First, actors perceived landscape composition in 2018 as tree-crop dominated with large settlement areas and smaller proportions of forest and food-crop areas (Chapter 2). They perceived landscape configuration as showing signs of early segregation (Chapter 3). Farmers associated the 2018 landscape with direct provisioning of landscape services for subsistence and commercial benefits, while institutional actors related it primarily to economic and employment value.

Second, the forecasting exercise showed that actors foresee a continuation of current landscape trends after 30 years under the business-as-usual development trajectory. They expect the landscape to consist of expanded areas under tree crops – cocoa, oil palm, and rubber – and settlement with further declines in forest and food-crop areas. Citrus is expected to disappear from the landscape completely. Institutional actors expect an expansion of the mining area, contrary to farmers' expectations of a decline. Regarding configuration, actors expect that the large and homogenous cocoa, oil palm, and settlement areas will position the landscape at the extreme segregation side of the continuum. Actors associated the business-as-usual future with increased incomes from tree crops and market-economic activities (Chapter 4). They also associated the landscape trends with adverse environmental and socio-economic effects. These include land degradation, declining water quality and quantity, sudden seasonal changes, pests and diseases, scarcity of timber and non-timber forest products and local foods, and high food prices (Chapter 4).

Third, participatory mapping revealed that – mindful of the implications of the business-as-usual future – actors desired a landscape in which tree crops and settlements dominate, but to a lesser extent than seen in the business-as-usual landscape future. In terms of configuration, they desire a landscape ranging from moderate to high segregation. The analysis also showed that the dominant tree crop at actors' locality and the degree of urbanisation in their landscape influenced their desired futures.

Fourth, the backcasting exercise showed that participants considered the following actions as critical to achieving their desired landscapes: (i) broad sensitisation to achieve a common understanding of landscape problems, (ii) actor engagement in the planning process, (iii) bottom-up policies backed by enforceable laws that take into consideration tradition and customs that protect landscapes, (iv) a joint coordinating team drawn from relevant landscape management institutions, including traditional authorities, to oversee the implementation of the plans, and v) joint monitoring and evaluation with feedback loops leading to adjusting initial plans in a cyclical manner. Actors also identified factors that constrain the achievement of their desired landscapes, such as multiple and conflicting tenure systems, costs, a lack of political will, and governmental policies that prioritise tree crops.

6.2.5 Tree-crop expansion in mosaic landscapes: spatial analysis and actors' perceptions and strategies

The central question underpinning this study was: how does tree-crop expansion affect the structure and multifunctionality of landscapes, and how do stakeholders perceive the dynamics and effects and adopt strategies to address them? This question is particularly relevant and topical considering that Ghana has a national tree-crop policy that targets productivity, food security, environment, and livelihoods in landscapes after many years of prioritising cocoa and oil palm for the market (MoFA, 2012). Furthermore, the country has recently established a Tree Crop Development Authority, similar to the Ghana Cocoa Board (COCOBOD). This agency is to spearhead the national scale commoditisation of five other tree crops in addition to cocoa and oil palm (Communications Bureau Government of Ghana, 2020). This plan will potentially intensify the spatial competition among land uses in landscapes.

Spatial-temporal analysis revealed an expansive development trajectory of cocoa and oil palm in the landscape, resulting in the doubling of areal coverage of the crops over the space of 29 years. The expansion of tree crops has had structural effects with inherent functional and socio-economic implications. The expansion of tree crops had significant effects on other land-cover types making up the landscape (Chapter 2) and reshaped the structure of the entire landscape (Chapter 3). Particularly mature fallow and forest patches outside forest reserves previously intentionally left as boundaries between adjoining farm plots have been lost to cocoa expansion. Oil-palm expansion mainly occurred on food-crop areas and forest patches in marshy areas and the most humid areas.

Landscape actors (mainly farmers) are aware of the structural dynamics in the landscape and the associated loss of food-crop and forest lands (Chapter 5). While actors acknowledged relatively high economic gains associated with tree-crop establishment and expansion in the landscape, they were also concerned about the adverse effects. These include increasing farm input requirements and costs, pollution by agrochemicals, quantitative and qualitative loss of biodiversity and landscape services, including non-timber forest products and essential services like food and water (Chapters 4 and 5). These adverse effects have implications for actors' use of landscape services, leading to using alternative sources, abandoning the use of specific services, or substituting with domesticated, technological, or synthetic alternatives (Chapter 4). Landscape actors have a clear vision of how to deal with the dynamics and associated effects (Section 6.2.4).

6.3 Contributions to landscape studies

6.3.1 Contribution to the debates

The study adopted a spatial-temporal view as the overarching lens for analysing the effects of expanding tree-crop production in landscapes. It draws inspiration from and engages with four landscape theoretical strands: integration-segregation theory, the land sharing and land sparing debate, integrated landscape approaches, and landscape services and trade-offs. The conceptual framework in Chapter 1 illustrates how these concepts and theories were integrated to examine the effects of commodity tree-crop expansion on the structure and multifunctionality of the landscape, actors' perceptions of effects, and their response strategies to trade-offs in transitioning landscapes. In this section, I reflect on how the theoretical framework that guided this research built on these strands and how this research contributes to the theoretical debates.

Integration-segregation theory explicitly acknowledges the spatial dynamics associated with landscape transitions that allocate land uses for mixed and specialised functions. The theory suggests that landscape structure (composition and configuration) evolves through transitions from extreme integration to extreme segregation of functions along a continuum of varying tree-cover densities (Brandt, 2003; van Noordwijk et al., 2014, 2012). This theory provided a valuable spatial lens to investigate the effects of tree-crop expansion in landscapes (Chapters 2 and 3). Moreover, presenting the framework to farmers and institutional actors triggered actor engagement in thinking about the structure of plausible landscape futures (Chapter 5). Chapters 2 and 3 showed that the study landscape is transitioning towards increasing segregation, compromising the provision of natural landscape services.

Although relevant in explaining the combinations of landscape functions associated with transitions and their trade-offs, the theory so far remained conceptual (van Noordwijk et al., 2014). This study took the theory forward by operationalising the structural properties that change with transitions for measurement. I developed a composite index, the landscape structural state index (LSSI), which integrates measures of changes in relevant spatial dimensions into a single value indicating the position of a landscape on the continuum between integration and segregation (Chapter 3). The scaled index provides a simple but intuitive means of monitoring structural changes in landscapes. It is an easy-to-use tool for engaging actors without expertise in spatial technologies in discussions about landscape change. Although the index is fit for purpose, it requires application in other landscapes to fully assess its responsiveness in different contexts and over several time frames.

The *land sharing and sparing debate* revolves around the extremes of two contrasting strategies for achieving maximum agricultural production to meet global demands without compromising biodiversity conservation in landscapes. The land-sharing strategy involves integrating natural ecosystems and agricultural production into multifunctional landscapes to combine biodiversity conservation with food and commodity production in the same space. The sparing strategy proposes setting land aside for nature conservation while intensifying agricultural production in production landscapes to limit the demand for additional farming land (Green et al., 2005; Tscharntke et al., 2012). This study employed the land sharing and sparing debate to anchor the spatial analysis of the research in a topical debate of realising conservation and production in landscapes amidst land scarcity. Existing studies have focused on increases in yield per unit area of production lands and species richness and diversity to support arguments in favour of either sharing or sparing, paying little or no attention to other potential benefits (Cannon et al., 2019; Clough et al., 2011; Egan and Mortensen, 2012). The binary approach has received criticisms for its inability to address real-world complexities in landscapes resulting from multiple factors and diverse human-nature interactions. Several scholars, therefore, proposed a shift to more nuanced approaches that reflect the contextual realities of landscapes (Grau et al., 2013; Law et al., 2015; Mertz and Mertens, 2017). This study confirmed that multifunctionality in landscapes is not an ‘either-or’ situation and that a mix of both ‘sharing’ and ‘sparing’ is needed. A forest reserve (‘sparing’) remained a stable feature in the landscape, whereas unprotected off-reserve forest patches in the agricultural landscape have disappeared along with most natural landscape services, constraining the livelihoods that depend on them (Chapters 4 and 5). This implies that landscape strategies should not be one size fits all and be nuanced by an understanding of social-cultural, economic and environmental contexts. Such insights will influence the degree to which a strategy should lean to either side of the divide.

Landscape services are the contributions of landscapes and landscape features to human wellbeing (Bastian et al., 2014). The contributions result from natural processes and functions of landscape features and their spatial interactions. They are influenced by human manipulations of the landscape motivated by social, cultural and economic values (Bastian et al., 2014; Termorshuizen and Opdam, 2009). Viewed as a spatial human-ecological system (Termorshuizen and Opdam, 2009), a policy or actor-led prioritisation and spatial dominance of some features mean less of others, leading to potential trade-offs in the supply of landscape services (Feurer et al., 2019; Willemen et al., 2012). *Trade-offs* refer to the consequential reduction in the provision of one landscape service arising from the increase in another service due to human management decisions in landscapes (Rodríguez et al., 2006; Turkelboom et al., 2018). Given the trade-offs, the actions and inactions of actors towards adapting to the situation and ensuring their wellbeing are considered *response strategies* (Feurer et al., 2019; Turkelboom et al., 2018).

This study combined the three landscape concepts – landscape services, trade-offs and response strategies – and their causal linkages to generate insights into the changes in the availability of landscape services due to tree-crop commodity expansion and actors’ surviving strategies. Specifically, the landscape service concept helped embrace all services and substitutes that landscape actors resorted to in the face of trade-offs. Thus, the study developed a conceptual framework for investigating the changing use of landscape services, sourcing patterns and the factors that influence actors’ responses as a landscape transition between integration and segregation.

Integrated landscape approaches are governance strategies and processes that aim to mobilise multistakeholder groups to negotiate trade-offs between different objectives and land uses and achieve multifunctional landscapes (Freeman et al., 2015; Reed et al., 2020, 2017; Ros-Tonen et al., 2018). Key principles for successful landscape approaches include a common landscape concern, multi-actor negotiation, joint reflection and learning, and knowledge pluralism to understand the landscape context, including losers and winners of landscape decisions (Bürgi et al., 2017; Sayer et al., 2013). It is a recommended approach for marrying biodiversity conservation, agricultural development, climate mitigation (REDD+) and adaptation, and landscape planning (Duncan et al., 2021; Svensson et al., 2020). An integrated landscape approach was beneficial to this research as a guiding framework to assemble actors from different locations and with diverse interests to negotiate their desired landscape while reflecting on current trends.

Although widely acknowledged as a potential panacea to addressing complex landscape goals and problems, integrated landscape approaches face several criticisms and implementation constraints. Its criticisms at the conceptual level include the multiplicity of definitions, failure to address power inequalities, uncertainty about effectiveness, and limited operational frameworks and applications in reality (Arts et al., 2017; Foli et al., 2018; Pfund, 2010; Riggs et al., 2021). Furthermore, the concept focuses more on governance structures and processes, empowerment and social learning, with little or no consideration for landscape ecology and climate moderation and resilience (Duncan et al., 2021; Reed et al., 2021). Similarly, issues related to landscape services are almost non-existent in the literature on landscape approaches. This study developed and applied a methodological framework for engaging landscape actors in negotiations about their landscape's future (Chapter 5). The method challenged actors to view and understand dynamics in landscape composition and configuration, which together influence the availability of landscape services at a point in time. The methodology enables a collective reflection on the current state of landscape composition and configuration, followed by forecasting into the future. Based on the identified challenges associated with the business-as-usual future of the landscape, actors mapped out their preferred futures through negotiations. They identified actors and their roles in creating the new future in a backcasting fashion. Integral to the method is the joint monitoring and evaluation leading to the adaptation of initial plans. The inherent temporal reflections and comparison of the state of the landscape in terms of composition and configuration and the socio-economic and cultural benefits and challenges over different periods make the method a suitable joint monitoring and evaluation tool. This will contribute to the short- and long-term joint evaluation of the effectiveness of integrated landscape approaches where they have been implemented. The proposed methodology is flexible enough to allow for adaptations to suit the contextual realities in landscapes.

6.3.2 Methodological contributions

The study made three methodological contributions to landscape studies. First, the study is among the first that explicitly separated cocoa from forest in landscape classification schemes and mapping using medium resolution satellite data. This is a departure from the use of broad categories like open forest or agriculture, which masks the actual effect of cocoa dynamics in landscapes (Acheampong et al., 2019; Barima et al., 2020; Oyinloye and Oloukoi, 2012). For example, the explicit separation of forest and cocoa avoids erroneous conclusions about forest dynamics, as in Acheampong et al. (2019), who assumed an increase in forest area based on a misclassification of tree-crop areas as forest. This led to their postulation that a process of 'deforestation in disguise' was occurring: a seeming increase in canopy cover was actually a replacement of forest cover with cocoa. The separation in this study was possible through the combined application of both visual and algorithm-based interpretation of satellite data (Chapter 2). This success has inspired other studies to explore advanced methods and data to separate perennial crops like cocoa and oil palm from other land categories to better understand their dynamics relative to other landscape components (Ashiagbor et al., 2020; Benefoh et al., 2018; Elisha et al., 2021; Numbisi et al., 2019).

Second, the study operationalised integration-segregation theory by identifying the structural properties that change as a landscape transitions between the extremes of integration and segregation (Chapter 3). The spatial dimensions of such structural properties were matched with landscape metrics that measure such parameters. With the landscape metrics, the spatial properties can be measured and monitored independently over time. Furthermore, the study successfully explored the development and application of a composite landscape structural state index (LSSI), which integrates measures of spatially dynamic properties to position a landscape on the integration-segregation continuum in a transitioning landscape (Chapter 3). It allows the tracking of a landscape's trajectory on the continuum over time. With such an index, it is relatively easier to engage non-spatial experts in discussions on landscape change.

Third, this study contributed to the operationalisation of integrated landscape approaches by developing a participatory spatial scenario-development approach (Chapter 5). The approach integrated participatory methods like focus group discussion, forecasting, backcasting, and participatory mapping to stimulate discussions on landscape dynamics and its consequences, common landscape concerns, and negotiated consensus on actors' desired landscape. The approach triggered actors' reflections about the current state of their landscape and its plausible futures. The approach significantly relied on visualising actors' perceptions of current and future landscape dynamics and the actions and institutions needed to achieve the desired future landscapes. The display of a live Excel pie chart of land-cover proportions during the discussions and using a base map in the participatory mapping exercise confronted actors with the trade-offs, spatial competition, and finiteness of the landscape. Furthermore, a visual tool (the configuration scale, see Figure 5.4) developed for this study enabled actors to explicitly share their perceptions of the spatial arrangement of features (configuration) in landscapes. Although the broad strokes of the approach were defined, there was room for experimentation and innovation in the facilitation process to sustain interest and encourage participation, reflection and negotiation. This allowed for the adaptation of the method to suit unplanned situations and to refine the rules of engagement.

6.4 Methodological reflections

In this section, I reflect on the methodological choices made during the research. First, as inferred from the preceding sections, I chose a mixed-methods approach to this research, employing methods and tools from geospatial and social sciences, including participatory scenario building. This combination was helpful in 1) investigating both the biophysical and social dimensions of a complex socio-ecological system longitudinally, 2) triangulating research findings, and 3) revealing the nexus and interactions between the biophysical and social aspects of the researched system. However, despite the useful combination, it also had some downsides.

First, stretching beyond disciplinary and epistemological divides requires considerable time to become familiar with and gain the required insights into each method for correct and diligent application. I found the decision to analyse the changes in landscape structure as a prerequisite baseline for collecting social data time-consuming. In hindsight, the spatial characterisation of landscape and social data collection could have been executed concurrently.

Second, the research initially aimed to identify decadal trends of the footprints of tree-crop expansion in the landscape since the 1970s. However, due to the limited availability of satellite data arising from the frequent cloud cover in western Africa, haziness, and fewer satellites passing the area in the past, eventually, only two time points 1986 and 2015, covering a 29-year period, could be compared. This situation led to the use of a 2015 Landsat image while field data for training and accuracy assessments were obtained in 2018. This constrained the development of historical trends of commodity crop expansion and associated structural changes in the landscape and exposed the land-cover classification to errors. Assuming that some areas remained unchanged throughout the period, the field data was complemented with data extracted from Google Earth's high-resolution database to classify the recent image. The absence of historical data for conducting an accuracy assessment on the land cover from the older satellites image (1986) motivated the use of the principle of unchanged areas to guide the classification and accuracy assessment. Cognisant of potential errors, the maps and results from their analysis were subjected to validation by landscape actors in a workshop during the Inclusive Values Chain Collaboration project's learning platforms (Chapter 5) to increase the confidence in the results. However, this by no means implies that the maps derived from satellite images are free from potential classification errors.

Third, although inspired by the work of van Noordwijk (2012), the construction of the landscape structural state index was somewhat exploratory. The use of data from only two time points affected the ability to rigorously evaluate the robustness and sensitivity of the landscape state structural index, which is a secondary product of the satellite data. Although considered fit for purpose and a proof of concept, there is a need for further experimentation with data from different landscapes and over different time lengths to be certain about its robustness.

6.5 Limitations of the research

The research has illustrated the structural and social responses to landscape changes due to the continuous expansion of commodity tree crops. However, some limitations were noted during the implementation of the research.

First is the limited availability of satellite data in the study area. As already noted in the previous section, instead of a decadal analysis from the 1970s, the study settled for one long epoch spanning 29 years. This constrained the development of historical trends of commodity crop expansion and associated landscape structural changes. The use of data from only two time points also affected the use and ability to rigorously evaluate the robustness and sensitivity of the landscape state structural index, which is a secondary product of the satellite data. With the recent proliferation of land observation satellites and active remote sensors such as Sentinel 1and 2, the temporal resolution of data in the area will improve.

Second, in analysing the dynamics in the use of landscape services, the response strategies to variations in service availability, and the degree of substitutability of services in landscapes, this study did not deal with cultural, regulating, and supporting landscape services. The focus on provisioning services does not fully account for trade-offs and choices between the four different categories of landscape services. A more comprehensive insight into all categories of landscape services and their interactions is relevant for decision-making in landscape governance and management. Moreover, this study did not consider the broad range of cultural and economic factors that could potentially influence rural landscape dwellers' vulnerabilities to landscape changes and their capacities to adopt response strategies. This limits the full understanding of people's vulnerabilities to landscape change and their options for survival.

Finally, the strength of integrated landscape approaches lies in negotiations to reach a consensus among and between actor groups with competing interests. However, constrained with time and funds, this study was unable to move beyond engaging similar actors and bring different types of actors to the discussion table. In the absence of that higher-level engagement between actors with different interests, we missed the opportunity to assess power asymmetries and conflicting interests across scales, which is relevant to the implementation of an integrated landscape approach.

6.6 Recommendations

6.6.1 Suggestions for further research

Several knowledge gaps emerged during the research. First, this research has successfully operationalised and developed the landscape structural state index to quantify the position of a landscape on an integration-segregation continuum. However, there is still an avenue for more research to assess its robustness by applying the index in different landscapes and at different temporal and spatial scales. Scientific inquiry is needed into the sensitivity of the index to changes in the individual spatial dimensions of the landscape.

Second, this research has shown that landscape interests are varied, and decisions are nuanced by context-specific factors. Yet, scholars proposed and advocated for sharing, sparing and other variants based on expectations of agricultural yields and biodiversity calculations, without much recourse to landscape-level social, economic, historical, and economic understanding. For landscapes that provide services for the survival of people, more research is needed to gain insights into the effects of these factors on sharing and sparing choices. In addition, the potential socio-cultural effects of landscape decisions and those on people's livelihoods should be modelled and evaluated before implementation.

Third, the use and sources of landscape provisioning services, as well as people's response strategies to changing availability, have shown to be context-specific and dynamic. This finding is compelling to extend the investigation into other landscape service categories and consider response strategies in the face of limited availability. Furthermore, displacement of landscape services introduced proximity issues that potentially constrain actors' options for a response strategy. This study has not considered the distance to sourcing areas of landscape services and other socio-economic factors that potentially affect actors' response strategies and capacities to adapt. This, too, warrants further research. Finally, further research is needed on crucial factors such as income and culture that potentially influence peoples' use and response strategies.

Fourth, integrated landscape approaches show promise in addressing and negotiating trade-offs between land uses and services in landscapes. The methodological framework developed in this research has demonstrated potential for engaging actors with diverse interests in developing plans for their landscapes. However, further (action) research is needed to bring actors with diverging interests – such as farmers and institutional actors (district government, local representatives of national government agencies) in this study – together to discuss and negotiate the differences in their preferred futures. Future research could also scale up, include additional actors, and implement the methodology beyond piloting. These additions allow assessing issues of power asymmetry in negotiations. Finally, the potential of the developed methodology as a participatory monitoring and evaluation approach in integrated landscape approaches should be further tested and concretised. These suggestions would provide insights into how to move from the negotiation table to implementation on the ground.

Finally, the growing dominance of commodity crops in landscapes calls for close monitoring of their spatial effects on the heterogeneity and diversity of landscapes. With the increasing advancements in spatial and spectral resolutions in remotely sensed data and methods, future research should focus on species identification and mapping of commodities like rubber and citrus, which sometimes are misclassified as forests.

6.5.2 Recommendations for policy and practice

The research revealed that commodity tree crops (especially cocoa and oil palm) currently dominate the previously mosaic landscape and shift its structure to one that is segregated into relatively homogenous areas. Over the years, the expansion of commodity tree crops has happened at the expense of food-crop areas and forest patches, particularly outside forest reserves. This has caused a decline in available landscape services relevant to the wellbeing of rural communities. The following recommendations are made for the consideration of policymakers and practitioners involved in landscape management and governance:

The assumption that forested rural landscapes are replete with food no longer holds due to the increased rate of food-crop land conversions to commodity tree crops, prioritised by the national government and driven by economic gains and an assured market. The Crop Directorate of the Ministry of Food and Agriculture (MoFA) should intensify extension services that promote high-yielding but environmentally sustainable food-crop production for subsistence and sale. Such services must encourage and include innovative means of integrating food crops into tree-crop farms, especially in oil palm areas, to avoid and reduce food insecurity.

Farmers should be encouraged to maintain a network of forest patches in the landscape between farm plots and in ecologically sensitive areas such as those along watercourses and marshy areas to serve as habitats for wildlife and hotspots of non-timber forest products that support livelihoods. This should complement the ongoing collaborative effort by the Forestry

Commission and Ghana Cocoa Board under the Ghana cocoa REDD+ programme[12] to promote the incorporation of 15-18 shade trees per hectare[13] in cocoa plantations.

Landscape programmes and interventions that embark on landscape services as a motivation to trigger and promote conservation actions among farmers and landscape inhabitants should employ new incentives to cover the opportunity costs of maintaining nature. These may include performance-based premiums and payments for ecosystem services. These incentives have become imperative because the sense of urgency to act among landscape actors has weakened because of the growing availability of alternatives to naturally occurring landscape services.

The analysis of satellite images and the participatory scenarios showed that the reserved forest faces threats of encroachment in the future with negative implications for landscape services and livelihoods. Efforts by the Ghana Forestry Commission and the district-level Departments of Food and Agriculture are not adequately achieving their targets for forest protection and food-crop production (MLNR, 2012b; MoFA, 2017, 2007). Authorities and policymakers should develop and implement inclusive land-use plans with a focus on multifunctionality to meet the needs of the multiple actors in the landscape. An integrated landscape approach such as the one piloted in the study presents an opportunity for cross-sectoral collaborations in planning a landscape in a way that reduces trade-offs between landscape services. Such planning processes should consider landscape composition as well as configuration as both influence the diversity, quantity and quality of landscape services.

[12] Ghana government's flagship programme aimed at reducing carbon emission in the cocoa through shade-tree planting, avoiding illegal logging and mining and promoting climate smart cocoa production approaches in cocoa landscapes.

[13] The recommended number in manuals and guides for cocoa extension in Ghana.