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Diversification and Adaptive Capacity across Scales in an Emerging Post-Frontier Landscape of the Usumacinta Valley, Chiapas, Mexico

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Diversification and adaptive capacity across scales in an emerging post-frontier landscape of the Usumacinta Valley, Chiapas, Mexico

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SUMMARY

This study investigates impacts and implications of recent landscape change in rural Mexico, through a case study in the Usumacinta Valley of eastern Chiapas. It addresses types of livelihood diversification strategies associated with changing land cover from 1984–2013, and the processes and roles that vary by actors and their scales of influence. After widespread forest loss and the expansion of extensive cattle ranching during the twentieth century, the region has exhibited several new economic and livelihood strategies in recent decades. Results from a combination of satellite imagery analysis and individual interviews from a wide range of land use decision makers demonstrate the dynamism of this landscape. The introduction of new crops, including teak, rubber and oil palm, as well as off-farm work, continue to shape the social and physical landscape and differentially impact the adaptive capacities of residents. Results indicate that small landholders often need to incorporate more crops into their agricultural portfolio and increase off-farm activities, leading to an atomization of livelihood strategies. By contrast, large landholders are able to pursue more specialized and lucrative agricultural opportunities.

Keywords: landscape change, diversification, adaptive capacity, small versus large landowners, agriculture

Diversification et capacité adaptative à différentes échelles dans un paysage émergeant post-frontière de la vallée de l'Usumacinta, Chiapas, Mexique

Z. CHRISTMAN, H. PEARSALL, B. SCHMOOK et S. MARDERO

Cette étude s'intéresse aux impacts et aux implications d'une récente transformation du paysage rural mexicain, à travers une étude de cas dans la vallée de l'Usumacinta au Chiapas oriental. Elle s'attache aux stratégies de diversification des moyens de subsistance associées aux changements de couverture terrestre entre 1984 et 2013, ainsi qu'aux processus et aux rôles qui varient selon les acteurs et leurs échelles d'influence. Après une perte généralisée des forêts et une expansion de l'élevage bovin extensif au XXème siècle, la région a été le théâtre de nouvelles stratégies économiques et d'obtention de revenus ces dernières décennies. Les résultats combinés d'une analyse d'imagerie satellitaire et d'entrevues individuelles auprès d'une grande diversité de preneurs de décision démontre le dynamisme de ce paysage. L'introduction de nouvelles cultures, telles que le tek, le caoutchouc et le palmier à huile, ainsi que le travail hors-ferme, continuent de modeler le paysage social et physique et d'impacter de manière différentielle les capacités d'adaptation des résidents. Les résultats indiquent que les petits producteurs ont besoin d'incorporer plus de cultures dans leur portfolio agricole et d'augmenter les activités hors ferme, conduisant à une atomisation des stratégies agricoles. À l'inverse, les grands propriétaires sont capables de poursuivre des opportunités plus spécialisées et plus lucratives.

Diversificación y capacidad de adaptación a diferentes escalas en un paisaje postfronterizo emergente del Valle del Usumacinta de Chiapas en México

Z. CHRISTMAN, H. PEARSALL, B. SCHMOOK y S. MARDERO

Este estudio analiza el impacto del reciente cambio en el paisaje en el Valle del Usumacinta, al este de Chiapas. Partiendo del modelo de medios de vida, se abordan los tipos de estrategias de diversificación asociados a los cambios en la cobertura del suelo desde 1984 a 2013. Igualmente, se consideran las diferencias en los procesos de uso de suelo derivados de la influencia de actores específicos. Después de la pérdida generalizada de los bosques y la expansión de la ganadería extensiva en el siglo XX, la región ha mostrado en las últimas décadas una serie de nuevas estrategias económicas y de medios de vida. Tanto el análisis de imágenes de satélite como las entrevistas individuales llevadas a cabo en 2013 a una amplia gama de actores regionales demuestran el dinamismo de este paisaje. La introducción de nuevos cultivos, como teca, caucho y

palma de aceite, así como el empleo fuera de la finca, continúan transformando el paisaje social y físico y afectando de manera diferenciada las capacidades de adaptación de los residentes. Los resultados indican que muchos de los pequeños propietarios se ven obligados a incorporar un mayor número de cultivos en su cartera agrícola y aumentar sus actividades externas a la finca, lo que lleva a una atomización de las estrategias de medios de vida. En cambio, los grandes terratenientes buscan oportunidades agrícolas más especializadas y lucrativas.

INTRODUCTION

Situated within the *Selva Lacandona,* between the forested landscapes of the Montes Azules National Park of Chiapas, Mexico and the Sierra del Lacandón National Park of Petén, Guatemala, the Usumacinta River Valley is now largely cleared of old growth forest. Heavy and widespread timber harvesting began in the mid-20th century, followed by a rapid expansion of cattle pasture (Howard 1988). This region has long been considered an important agricultural frontier of southern Mexico (O'Brien 1998). Now stretches of contiguous forest and zones previously used for smallholder agriculture have transitioned to larger, more consolidated agricultural systems and rangeland for cattle, further limiting available valley land. A restructured local cattle economy, expanding industrial oil palm cultivation, and teak and rubber plantations now dominate this previously forested landscape, creating a patchwork of land uses. The process of landscape-level diversification reflects the imprint of these new economic activities, as well as the different roles and opportunities available to the various land users, from indigenous communities and long-time inhabitants to recent speculators from other Mexican states.

Residents and local users of this landscape, including smallholders, cattle distributors, plantation owners, and cooperative partners, all strive to adapt to changing environmental and economic conditions. These changes in land use are driven by both distal and proximate land managers and users, as well as economic and political processes at multiple scales. Previous studies have promoted the importance of livelihood diversification to cope with shifting livelihood opportunities (Ellis 1998). Few studies, however, have considered how this process of diversification is mediated by varying access to land and different socio-economic situations among land managers.

This paper addresses landscape diversification and adaptive capacities, stemming from economic and environmental variability and change. The two central research questions are: 1) Are livelihood diversification strategies associated with the changing land cover observed from 1984–2013? and 2) How do diversification strategies vary by actors and their scales of influence? Drawing on McCusker and Carr's (2006) framework of the co-production of livelihoods and land uses, this study examines these questions through a case study in the Usumacinta Valley of eastern Chiapas. The study site presents both relatively rapid changes in land use, as well as shifts in livelihood during the study period. Over the last three decades, changing agricultural practices, expanded cattle pasture, and new crops for diversifying land management practices have emerged. Both local residents and commercial entities have changed their agricultural practices, sometimes with the support of governmental programs. We employ a mixed methods approach to characterize the diversification strategies employed by different land managers and the contexts that shape their ability to utilize and benefit from diversification. Methods employed include a historical review, satellite imagery analysis, field observations, and individual interviews with farmers, ranchers, and representatives of producer organizations and commercial entities.

This study contributes to previous research on livelihood diversification and land use change (Ellis 1998, Batterbury 2001, McCusker and Carr 2006, Saldaña-Zorrilla 2008) by highlighting the uneven drivers and impacts of landscape-level and economic diversification at different scales of land access and ownership. Our findings indicate that large landholders benefit from diversified agricultural options. Local land managers and smallholders, in contrast, have collectively pursued an increasingly broad range of economic activities that progress toward an atomization of land uses, characterized by discrete and unrelated activities. These activities, in turn, have produced an increasingly fragmented yet dynamic landscape. The combined impacts of population increase, agricultural subsidies for forest plantations, and national and international labour migration have led to both diversified and intensified economic and agricultural activities. These changes have occurred, in spite of smallholders' cultural affinity for *milpa* agriculture, a traditional maize swidden system (see Schmook *et al*. 2013).

Differential access to capital and governmental subsidies has further shaped the range of options for different actors (e.g. distributors, small and large landholders, etc.) to participate in the processes leading to these landscapes changes. The patterns of these impacts are also spatially variable. Results of this study suggest that smallholders may be inclined to adopt a strategy of atomization of livelihood strategies and land uses, engaging in a wide range of agricultural activities, often including off-farm employment, while large land holders can pursue more specialized and lucrative new opportunities.

Diversification as a strategy to increase adaptive capacity to economic and environmental changes and challenges

Changing environmental and economic influences act as perturbations to systems that support the livelihoods of local residents. Several similar frameworks exist in the scholarly literature to organize and describe the contexts and influences surrounding a human-environment coupled system (Gallopin 2006, Janssen *et al*. 2006, Head 2009), including the framework of "adaptation," common in Anthropology (McCarthy

2001), "resilience," favoured by researchers of socio-ecological systems (Holling 1973), and "vulnerability" (Blaikie *et al*. 1994) in Geography and related communities. We employ the vulnerability framework as outlined by Turner and colleagues (2003), which encompasses three constituent contexts: exposure, sensitivity, and adaptive capacity. Communities, individuals, and businesses may be differentially exposed to the effects of these influences (their *exposure*). They may experience these influences to varying degrees based on both internal and external conditions at the time of exposure (their *sensitivity*). The ability of these actors to respond to a stressor, either by coping with the current situation or improving their abilities to experience or respond to future impacts, is termed *adaptive capacity*. Adaptive capacity has been used to describe both the responses to a wide range of situations and the strategies employed to both maintain and improve the conditions of those impacted (Smit and Wandel 2006, Saldaña-Zorrilla 2008, Eakin *et al*. 2010).

Vulnerability research often focuses on increasing adaptive capacities as an approach to reducing overall vulnerabilities. Diversification of livelihood activities has been suggested as a promising solution for smallholders facing a wide array of environmental and economic challenges with which they must cope from year to year (Ellis 1998, Steward 2007). Diversification, as defined by Ellis (1998), is a process that enables households to develop a suite of economic activities and a social support system to survive during difficult times and improve quality of life. Diversification of livelihood activities can improve a household's ability to adapt to stressful circumstances: if, for example, a drought compromises a crop yield, a family may draw on non-farm employment. Ellis suggests that diversification is a new approach to conceptualizing livelihood opportunities that stands in contrast to more traditional perspectives of economic change, where workers transition, cleanly, from one economic activity to another. Steward (2007) argues that diversification has become an increasingly important strategy in the face of economic, environmental, policy, and demographic changes. For instance, Batterbury (2001) describes how such a process of diversification allows Zarma farmers in southwest Nigeria to respond and adapt to various barriers and opportunities in a constantly changing landscape. In another example, Saldaña-Zorrilla (2008) characterizes strategies of southern Mexican agricultural communities to cope with the hazards of flooding and other weather-related events. Respondents sought aid from family networks and governmental programs, but Saldaña-Zorillo cites the challenges of diversification as an impediment to future preparedness. In spite of these potential challenges, the atomization of livelihood strategies, in which each activity offers a distinct and independent contribution, has been recognized as a microeconomic strategy to mitigate the negative impacts of failure of any individual activity (Adger 1999, Saldaña-Zorrilla 2008).

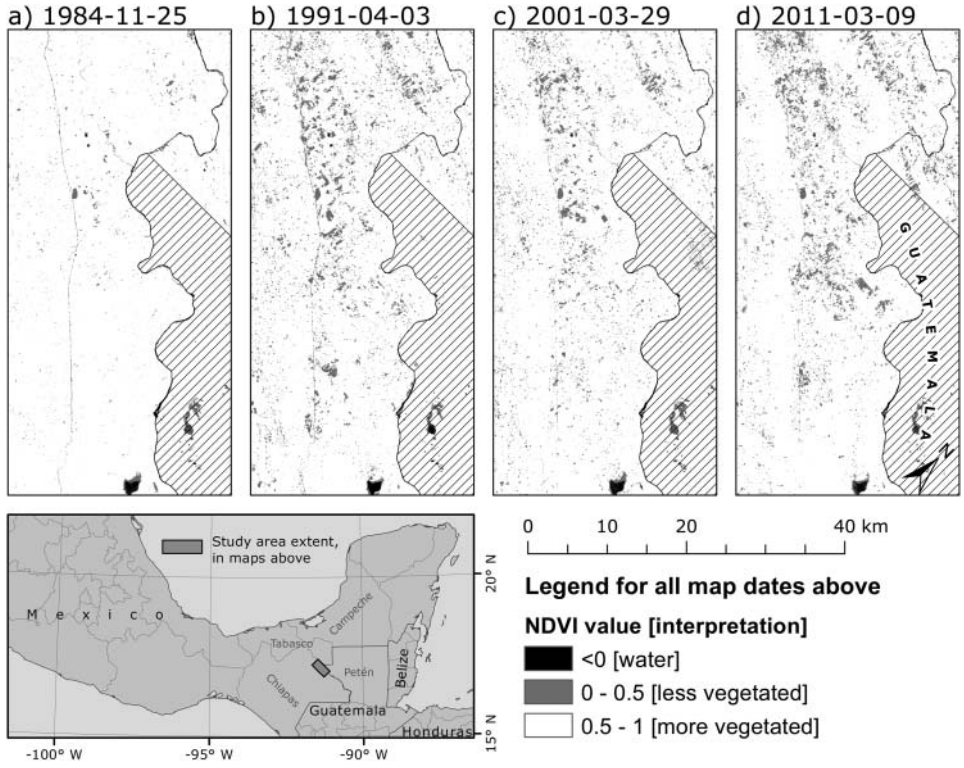
This diversification process has become pronounced over the last 40 years in many rural places, and is reflected in land use and cover changes. Ribiero Palacios and colleagues (2013) examined the relationship between livelihood diversification and landscape changes in the tropical Southern Huasteca of San Luis Potosi, Mexico. The authors found that local drivers, such as smallholder land management and population growth, as well as national and international drivers, including neoliberal policies and global market influences, created three different livelihood trajectories that all contributed to increasing landscape fragmentation. Landscapes situated, either physically or functionally, at the periphery of economic networks are recognized as *frontiers* (Schmink and Wood 1992, Jepson 2006). Based on fundamental improvements in access, technological implementation, and market integration, these frontier landscapes may intensify or diversify according to the proximate and distal pressures of new economic opportunities (c.f., Turner and Brush 1987). As external market pathways increasingly shape the economic activities, and activities centralize around local urbanizing centres, these landscapes are termed *post-frontier* (after Summers 2008, Slatta 2012). In post-frontiers, the diversification or displacement of land use activities manifest differently among actors at various scales (Browder *et al*. 2004), leading to varying capacities to adapt in the face of shifting economic and environmental conditions.

McCusker and Carr (2006) critique such studies of livelihood drivers of land use and land cover change and propose a framework that considers how livelihoods and landscapes are co-produced. They seek not only to identify causal agents of change in the land, but also to explain the social processes that produce changes in landscapes and livelihoods. McCusker and Carr (2006) further acknowledge ways in which power structures condition these intertwined changes. Such attention to power dynamics marks an important focus in discussions of livelihood diversification. Unpacking the social conditions associated with diversification reveals the complexity of processes linked to landscape changes. For instance, Ellis (1998) points out that diversification can reduce overall income in some cases, but that some households are willing to sacrifice a modicum of income for greater security. Additionally, not all households are able to diversify. Bryan and colleagues (2009) document that some farmers face multiple barriers to diversification as a strategy of adapting to changing climatic conditions in farming communities in Ethiopia and South Africa. In these communities, a lack of access to credit, land, and information prevented some farmers from diversifying their crops, even in instances where they were aware of potential benefits of crop diversification in the context of perceived changes in climate.

STUDY AREA

The region of interest is the Usumacinta Valley of Chiapas, Mexico, west of the border with Guatemala. The circuitous Usumacinta River and its tributaries flow more than 1 000 km from highland Guatemala to empty into the Gulf of Mexico. This study focuses on the Usumacinta Valley region southeast of the city of Palenque, spanning sections of the municipalities of Ocosigno and Palenque, near the border of the states of Chiapas and Tabasco, as illustrated in Figure 1. Land tenure across the valley varies, with the majority of people residing

FIGURE 1 *Study area in context and with NDVI vegetation classifications: a) 1984, b) 1991, c) 2001, and d) 2011*



in *ejidos*, in which land is held communally and use rights are allocated to individuals (Barnes 2009). Additionally, there is another community structure, called a *colónia*, in which individuals have direct ownership over their parcels, though the holdings are relatively modest, usually in the tens of hectares per resident.

The Usumacinta Valley of Chiapas has been experiencing notable changes in precipitation patterns in relation to its varied topography. At the edges of the valley floor, changes in slope are quite abrupt, with steep ridges bordering the valley basin. Elevation ranges from 7 to 722 m above mean sea level (amsl), with an average elevation of 279 m amsl and the valley floor at approximately 150 m amsl. The average rainfall (1990–2009) in the study area oscillates between 3800 mm in the North (near the city of Palenque), 2 200 mm in the Centre (near the community of Nueva Esperanza) and 2 700 mm in the South (near the community of Nueva Palestina). Across the study area, the average July precipitation for the period 1990 to 2009 decreased by 18 to 25 per cent, relative to the July average for the years 1960 through 1990. The average annual rainfall decreased up to 14 per cent over this period ('CCKP' 2014). One unique feature of precipitation in the area is the *canícula,* or midsummer drought, which is most severe during late July or August, depending on latitude. Additionally, certain intermittent weather patterns create conditions for a phenomenon known as *cabiñuelo* that combines rain with high heat, which poses another problem for crop cultivation.

Official land cover information for the valley is not precise in its categorization, due in part to the dynamism of the landscape. Woody vegetation across the valley is categorized only as *selva perennifolia*, or evergreen (non-deciduous) forest, and *arboreo alto*, woody cover of tall stature, with some sections of primary and secondary forest delineated. Agricultural and pastoral activities are only referred to as *agricultura temporal* (non-irrigated seasonal agriculture) and *pastizal cultivado* (cultivated pasture), respectively (Comisión Nacional Forestal 2012).

Based on its long history as a rural landscape whose residents focused primarily on subsistence agriculture, the Usumacinta Valley has long served as a frontier landscape (Howard 1988). However, the increasingly segmented cattle market, coupled with the recent introduction of tree plantations and other new economic opportunities, has shifted the landscape toward a post-frontier landscape, in which distal forces increasingly shape local markets and livelihoods.

DATA AND METHODS

This study 1) connects changes in land use and land cover with livelihood diversification activities, and 2) demonstrates how differential access to resources underlies the diversification processes in the Usumacinta Valley over the last three decades, through the use of a mixed methods approach. Changes in the landscape are described via a historical review of land use/land cover change through the 20th century and quantitative analysis of remotely sensed data from 1984–2011. Field observations from site visits and regional driving tours and in-depth semi-structured interviews conducted in May and June 2013 inform the assessment of historic context, livelihood diversification strategies, and the social dimensions associated with changing adaptive capacities.

Remotely Sensed Data

Imagery from the Landsat-5 Thematic Mapper was acquired via the USGS Earth Explorer for the following dates: November 25, 1984; April 3, 1991; March 29, 2001, and March 9, 2011. Imagery dates were chosen based on the availability of cloud-free imagery and (when possible) similar calendar dates of acquisition, to ensure comparable seasonal vegetation conditions. All images were converted to at-sensor reflectance values based on their initial collection conditions, after Chavez (1996), using Idrisi Selva (Eastman 2012) and Normalized Difference Vegetation Indices (NDVI) images were compiled (Tucker *et al*. 1981). Numerous studies relate NDVI to ecological characteristics (Cihlar *et al*. 1991, DeFries *et al*. 1999, Neeti *et al*. 2012). In this study, we interpret the range of positive values of NDVI as the presence of dense, healthy vegetation on the landscape. Due to the density and heterogeneous composition of the vegetation, this landscape is especially challenging to classify through automated methods. Because vegetation of any type has a high NDVI value, it is not possible to discriminate between cultivated and natural vegetation from NDVI alone. Further, vegetation types are not finely differentiated in the official government products (Comisión Nacional Forestal 2012). For ease of comparison and to indicate major landscape modification over this 27-year sequence, NDVI values, which range from –1 to +1, were thresholded such that values below 0 were regarded as *water*, values from 0–0.5 were regarded as *less densely vegetated* (e.g., pasture, early crops, or early secondary vegetation), and values from 0.5 to 1.0 were regarded as *more densely vegetated* (e.g. mature crops, dense secondary vegetation or forest). Though it is challenging to discriminate the composition of land use and land cover through this proxy alone, the temporal comparison highlights regions that experienced substantive changes in vegetation during this period (e.g., forest clearing, growth of secondary vegetation on a fallow field, or other similar shifts in land cover), which are then linked to specific economic activities (e.g. ranching) through "ground truthing" site visits. The research team visited over 200 sites in the study area in June 2013 to explore the current land use practices and to verify and interpret the results of the NDVI change analysis. The dynamism of this landscape and the influence of various economic activities may be indicated by the patterns of either continuous vegetation cover or some type of vegetation loss or regrowth during this the study period.

For each of the four imagery dates, area calculations for each of the three designated categories (water, less vegetated, and more vegetated) were tabulated. The thresholded images data were then quantitatively compared through a multidimensional crosstabulation matrix (Congalton and Green 2009) to identify regions of apparent persistence and change. Zones that experienced landscape transitions, including continual gains, continual losses, or *swap* (changes of trend between gain and loss) over this time period, demonstrate the dynamic composition and use of this landscape.

Individual Interviews

Seventeen semi-structured interviews were conducted in May and June 2013, including a total of twenty individuals, identified with the aid of a local guide who assisted with land use and property regime recognition, visits to communities and institutional offices, and mediating contact with references mentioned by previous participants (*snowball sampling*). Interviews included representatives of the most common land use managers, including smallholders practicing rain-fed agriculture, cattle ranchers, cattle buyers/distributors, small and large plantation owners, commercial representatives and government employees and landless farmers (usually called *avecindados*) and smallholders (often termed *campesinos*) with a history of labour migration within Mexico and/or to the U.S. The interviews covered questions on demographics, climatic patterns and changes, land transitions, and economic activities, focusing on cattle, farming, and additional diversification activities. Interviews lasted from one to three hours and were conducted by this research team, in Spanish, audio-recorded with permission, and then transcribed for subsequent interpretation. Interview participants included residents of five communities (outlined in Table 1), a representative of a teak plantation located in the community of Pénjamo, and representatives of cattle and oil palm cooperatives in Palenque that represent producers in the study area. Interviewees included smallholder farmers who cultivated maize, medium landholders who cultivated maize and raised cattle for sale to regional distributors, and experimented with teak and oil palm cultivation, and large landholders, with significant investments in ranching and/or tree plantations.

TABLE 1 *Characteristics of interviewees' communities*

Community	Type	Number of landholders	Municipality	Area of community (ha)
Nueva Esperanza Progresista	Colónia	107	Ocosingo	1021
Nuevo Francisco León	Ejido	226	Ocosingo	2760
Once de Julio	Colónia	14	Ocosingo	128
El Clavo	Ejido	89	Palenque	1057
El Eden	Ejido	95	Palenque	1249

RESULTS

Land cover changes

The forest, water availability, and topography have historically made the Usumacinta Valley an attractive site for economic activities, including logging, farming, and ranching, since the 1800s. Numerous indigenous groups have lived in the Mexican *Selva Lacondona* since the height of the Maya Classic Period (c.f. Golden and Scherer 2013). Now, the original lowland Maya communities have dwindled, and the relatively few current indigenous inhabitants most often trace their lineages to highland communities of central Chiapas, west of this region (Howard 1988). From 1859 to the middle of the twentieth century, logging companies profited from the export of timber from the Selva Lacandona (de Vos 1996). O'Brien (1998) describes the phases of logging that encouraged increasing clearing and utilization of the land. The early phases of logging, though labour intensive, were less detrimental to the forests than the mechanized logging efforts led by commercial entities financed by U.S. business investments in the 1950s. By the early 1970s these private timber companies sold their logging rights to the state, once they had exploited the land as much as was profitable. The state initially aimed to extract and sell the remaining timber in the Lacandón, but struggled to make a profit from the remaining forests. Ultimately, the governor of Chiapas banned logging in 1989. O'Brien (1998) indicates that the logging roads facilitated extensive access and ultimately colonization of many regions in Chiapas, rendering it a desirable agricultural frontier and leading to further clearing of the forest.

With the decline of the timber industry in Chiapas and increasing accessibility to partially cleared land, ranching activities expanded rapidly, particularly around the northern border of the forest near Palenque (Howard 1988). From 1940 to1980, the government launched policies and programs to encourage ranching, resulting in the conversion of agricultural land into pasture (O'Brien 1998). By the 1970s, with much of the agricultural land converted to pasture, ranchers and small landholders began to push further into the Lacandón, recognizing that cattle-raising was more profitable than agriculture.

Timber extraction, deforestation, and immigration have rendered the rainforest a patchwork of secondary growth and agricultural fields, punctuated by conservation zones and archaeological sites. Multiple studies have documented the systematic deforestation of the *Selva Lacandona* (O'Brien 1998, de Vos 2003). Despite the complexity of land use and land cover changes over the past 60 years, concerns over extensive deforestation have characterized many studies of the Selva Lacandona and pitted *users* of the forest against *conservers* of the forest (O'Brien 1998). These concerns are based on data-driven observations that documented a loss of two-thirds of the 1,500,000 hectares of the Lacandón forest by the mid-1990s.

The land change analysis of remotely sensed imagery over the last three decades reveals that the region, though experiencing progressive clearing, remains highly dynamic, in contrast to the reported history of unidirectional deforestation. Based on the three-class assessment from the NDVI values, the region is still highly vegetated (including natural and managed forest stands, secondary growth, active and fallow agriculture, and pasture), but has undergone substantial land use/cover transitions over the time of the study period. In 1984, 97.83 per cent of the landscape was considered *more densely vegetated*. This figure fell to 92.15 per cent in 1991, rose slightly to 93.98 per cent in 2001, and fell again, to 92.23 per cent, in 2011. The *less densely vegetated* area was 1.66 per cent of the region in 1984. It rose to 7.44 per cent in 1991, dipped to 5.58 per cent in 2001, and rose again to 7.43 per cent in 2011. The area of surface water, including the river and wetlands, began at 0.52 per cent, falling to 0.35 per cent by the end of the 27-year study period (Figure 1).

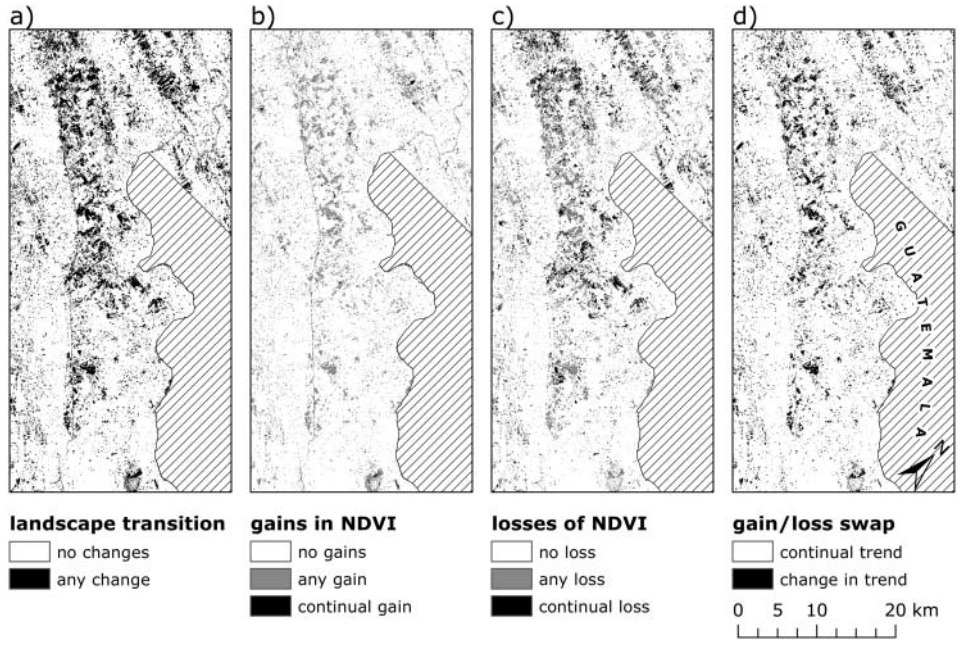
The areal and comparative calculations of thresholded NDVI values demonstrate changes in the composition of the landscape, illustrated in Figure 2, correspond to many of the transitions mentioned in the interviews and referenced in historical accounts (Howard 1988). Between 1984 and 2011, 83.88 per cent of the landscape experienced persistence, in which there was no change between the three vegetated cover classes across any of the four time steps (i.e., remained consistently *water*, *less densely vegetated*, or *more densely vegetated* in 1984, 1991, 2001, and 2011). It follows that 16.22 per cent of the landscape experienced some change in the ascribed category during this period. Three such shifts were further explored. Locations (defined as individual 30m pixels in the change analysis) that decreased in NDVI class from *more densely vegetated* to *less densely vegetated*, or from *less densely vegetated* to *water* any time during this sequence characterized 15.11 per cent of the landscape. Continual decreases in NDVI class occurred in 5.73 per cent of the landscape over the entire study period, with no increases across any time-steps. Conversely, 10.39 per cent of the landscape experienced a categorical increase in NDVI over at least one time-step of the sequence, and 1.01 per cent of the study area consistently increased in NDVI, with no decreases across any time-steps. A substantial portion of the landscape, 9.38 per cent, experienced a swap between both loss (decrease in NDVI class) and gain (increase in NDVI class) during this time sequence.

The land change analysis demonstrates the continued pattern of forest loss described through the historical analysis and extends it to illustrate the dynamic swap of land cover and conditions through recent decades. The footprint of the expanding extensive land uses has been verified from GPS-referenced visual observations. Narratives of interviewees reinforce these connections, demonstrating the dynamic transitions resulting from the development of this landscape.

Diversification strategies

Interviews with a variety of land managers and users, including smallholders, cattle ranchers, cattle distributors, and commercial representatives offer insight into livelihood strategies linked to the landscape changes described above. Reflecting the complexity of a dynamic landscape, the interviews

FIGURE 2 *Types of landscape transitions experienced over the sequence from 1984-1991-2001-2011 in the Usumacinta Valley, including a) presence of some landscape transition, b) locations experiencing a gain in NDVI over some time step, c) locations experiencing a loss in NDVI class, d) locations experiencing both gains and losses in NDVI over the sequence*



revealed a livelihood diversification process with varied contexts, implementations, and results. *Milpa*, a mixed crop swidden cultivation system, was originally the most common agricultural practice in the region. It remained the most widely and persistently pursued form of land use. Over the last three decades, though, the rise of cattle ranching has replaced some agricultural fields and fuelled land-clearing activities on increasingly marginal land. The establishment of tree plantations, including teak, rubber, and oil palm, marked a recent land use transition. The process of livelihood diversification was neither universal nor linear, with many different possible practices and implementations across different communities and land managers.

Milpa

> *"People in the community mainly cultivate maize and beans, it has always been like that. Years ago, they also used to plant [jalapeño] peppers, but now just a few of them still plant peppers."*

This smallholder farmer's comment reveals the persistence of *milpa* subsistence agriculture across Chiapas. Subsistence agriculture contributed to some of the original extensive clearing of the older growth forest, primarily by migrant labourers hired by timber companies (Howard 1988), and today many families continue to rely on subsistence agriculture. According to this farmer, maize is the main staple for families in his community, and every family cultivates 2–3 hectares of maize. Each hectare can potentially yield around 2 tons of maize, which is enough to feed a family and a few animals for a year. While there may occasionally be some surplus maize for sale, the market for maize is extremely local. Despite extensive areas devoted to cattle ranching in the valley, one interviewee reported that around 80 per cent of the people in his community only cultivate maize.

Maize, given abundant rainfall, is planted twice a year and cultivated under the *milpa* system. If there is abundant land, the fallow is longer (three years, which implies incipient woody vegetation regrowth). In contrast, if land is scarce, as it is in most communities, the fallow period may be as short as one year. With fields fallowing for only a year, almost no burning (for the purpose of clearing) is required. Only in a very few cases, where the fallow period is eight years or more, is burning required to clear the secondary growth. This clearing process produces the dynamic land cover observed through the remotely sensed data, with fields following a cycle of clearing, crop growth, secondary growth, and a return to clearing.

Despite the widespread persistence of maize cultivation, farmers faced a numbers of issues. For instance, farmers who cultivate without allowing their fields a sufficient fallow period have to use fertilizers; also, the weather phenomena of the *canícula* and *cabiñuelo* may severely impact maize cultivation if the timing intersects with a critical growth period. Many farmers sought additional economic activities outside of maize cultivation, to generate supplementary income and remain resilient in the face of environmental stressors that compromised reliable harvests.

Ranching

Ranching became the first widespread effort to diversify livelihoods in the region in the later 20th century. Unlike maize cultivation, ranching activities mark a more persistent transition in the landscape. Cattle continuously graze in the fields, allowing almost no secondary growth to occur as opposed to

fields intermittently cultivated with maize and allowed to fallow. Further, cattle require fairly large tracts of land, fuelling some of the land clearing observed in the 1984–2011 imagery and land cover change analysis (Figure 2c).

Ranching became an increasingly common economic activity in the Usumacinta Valley following the demise of the logging industry in the 1970s (Howard 1988) and was encouraged with government subsidies during the 1980s. Many of the farmers explained that cattle raising was more lucrative than maize cultivation, though several farmers shared some concerns. Cattle require a certain amount of land to thrive, and many farmers lacked access to land or capital to purchase land. Some ranchers must rent land to graze their cattle, and the rent during difficult times, like droughts, may be 80 to 100 pesos ($6–7 USD) per month for each animal. Further, ranchers in Chiapas raise heifers for the first two years and then sell them to larger regional ranchers from the neighbouring states of Tabasco and Veracruz. The regional ranchers then fatten the cattle and either sell them to another distributor or send them to slaughter. The Chiapaneco ranchers' participation in the early period of cattle-raising leads them to take on the most substantial risk, because the cattle are most prone to disease in the first two years. Additionally, the heifers, because they are still relatively small after two years, command lower prices than cattle that are older and ready to sell for slaughter.

According to one interviewee, the government subsidies that enabled many ranchers to begin their operations have become more limited in availability, thereby complicating farmers' diversification of maize cultivation with cattle raising. In the 1990s, the government made available loans for cattle, and most people in this interviewee's community took advantage of the loans. As of May 2013, far fewer subsidies were available. Many of these remaining subsidies were only available to largeholder ranchers. In part, these largeholder ranchers had more access to information and the required capital through their networks, so it was easier for them to take advantage of these opportunities.

Tree Plantations

The rise of tree plantations, including teak (*Tectona grandis*), rubber (*Castilla elastica*), and oil palm (*Elaeis guineensis*), represents the most recent trend in livelihood diversification. Like cattle ranching, tree plantations require large tracts of land to be profitable and mark a true transition in land cover, as opposed to the dynamic variability of subsistence agriculture. Unlike ranching, however, tree plantations also contribute to overall vegetation cover as the trees mature. With respect to livelihood diversification, tree plantations also carried the promise of more economic returns than ranching or maize. However, these opportunities were limited to a small and elite segment of land managers in the region who were able to cope with the waiting time to maturity in anticipation of future markets. In spite of these challenges, medium-scale landholders sought to enter this market, as did groups of smallholders who were able to collectively amass land and resources, which interviewees reported occurring on a limited scale.

The potential profits from teak sales captured the interest of large landholders, particularly those with access to start-up capital and business networks. Teak cultivation initially started in Campeche, but Chiapas was recognized as a more fertile and desirable location. As one businessman, owner of a timber company, who started teak plantations in Campeche in 2006 observed:

> *"In Chiapas, from one big available area, 100 per cent can be useful for planting teak, but in Campeche, maybe just 30 per cent, because the land is not suitable. So at first, Campeche looked like a good option because of the price of land, but not anymore—Tabasco and Chiapas are much better."*

The businessman also emphasized the benefits of heavy rainfall in Chiapas for teak cultivation, though he noted that if communities were willing to sell some land, it was typically not the high quality land. For instance, an existing plantation that was expected to produce 220 m^3 of teak may only realize 160–170 m^3, which would be enough to recover the investment, but yield only a small profit. The businessman explained that he also would endeavour to highlight the employment opportunities afforded by the plantations:

> *"When I talk to people about teak plantations I tell them: Look, when a forestry company establishes, there are a lot of job opportunities, in comparison with a thousand hectares for cattle, employing just four guys, a forestry plantation may hire at least 60 people permanently and more people temporarily."*

While these employment opportunities may sound promising, such promises are against the backdrop of a quest for more land. Every year the company plans to expand its land holdings by 1 200 hectares, and Chiapas is the new frontier of expansion.

Despite the initiative for expanding land holdings, the teak company also supported an alternative business model that supported independent farmers aspiring to cultivate trees. The company assists these farmers and helps them to find a market for their product. This alternate model provides a better land tenure scenario for small- to medium-scale landowners wishing to engage in teak cultivation. However, the plantations required not only a large investment up front, but also a 10- to 20-year wait for the trees to mature. Although there are some government subsidies for teak plantations, many of the subsidies are only accessible for commercial operations. For instance, the businessman informed us, CONAFOR (the Mexican National Forest Commission) provides subsidies for teak and other forest plantations, at 10 000 pesos (~$738 USD) per hectare, yet the recipient of the subsidy must already have a plantation established prior to requesting support. Additionally, CONAFOR visits the plantation to ensure that the trees have an 85 to 90 per cent survival rate before issuing the funds. Finally, the businessman explained, plantations require considerable investment, an estimated 120 000 pesos (~$8 850 USD) per hectare over the 20-year life of the trees.

Clearly, the teak industry opens up the most opportunities for the wealthiest landowners, many of whom are not from Chiapas.

Interestingly, the teak businessman commented that some communities were reluctant to include teak cultivation into their farming portfolio:

> *"In Southeast Mexico, the tradition of forest plantations is just starting. For example, in Veracruz, where the main activity is cattle ranching, around ten years ago, I started encouraging the farmers with really big lands to plant a few hectares of cedar and most of them didn't want to—just a few of them did it. People in this region are more likely to have cattle and plant maize."*

The businessman acknowledged that the reluctance was pragmatic, observing that many of the initial subsidies for tree plantations were aimed at providing trees rather than technical assistance. Many farmers, though enthusiastic about the prospect of a plantation, became discouraged by the money and work required to maintain the plantation until it is ready to harvest. Further, few landholders at any scale were certain about the price of teak. One interviewee commented that people say there is a buyer coming to pay one thousand pesos (~$74 USD) for each tree, but that this price quote was merely rumoured.

Oil Palm

The rise of the oil palm industry in the Usumacinta Valley provides insights into macro-scale drivers of landscape change, namely the role of international investment and speculation fuelling this intensive and increasingly widespread land use across the region. Oil palm production started in Mexico in the mid-1990s, but began booming in the region during the last 10 years. These palm plantations are visible in the satellite imagery from 2001 (in the lower centre of Figure 2c). A few major institutions have dominated the palm oil market: Palma Tica, a Costa Rican Company; AGROINSA, a Mexican company; and SAGARPA, the Mexican Secretary of Agriculture, Livestock, Rural Development, Fish, and Food Production, which has sponsored planting programs. Palm oil has a pervasive presence in the national and international food market, with the product commonly found in margarine, cooking oil, shortening, and many processed and packaged foods, such as chips (Khosla and Sundram 2010, Khoury *et al*. 2014).

While the extensive and mature palm plantations visible in recent satellite imagery clearly benefitted the large landholders capable of investing in this land use, interviews showed that small- to medium-scale farmers were increasingly targeted and occasionally interested in this practice. Palm oil companies were eager to encourage these smaller-scale farmers to cultivate the palms. For instance, one interviewee, a medium-scale land manager who historically practiced *milpa* cultivation and cattle ranching, decided to test oil palm planting. He requested the plants from SAGARPA in Palenque and received 650 plants at no cost. Despite the benefit of the free plants, the farmer received no extension services or instructions for cultivating the palms. He invests 5 000 pesos (~$369 USD) per year to maintain the land and continues to plant maize in between the palms to maximize the land use before the palm trees mature and begin producing fruit. While this farmer was hopeful about the profits from the sale of the palm fruits in several more years, he had no sense of the market or prospective buyers for the palm fruits.

Despite the curiosity and interest of some farmers and ranchers, others expressed scepticism over the environmental impacts of the palm plantations. A rancher at a nearby *colónia* noted that the trees required a substantial amount of water and that the plantations dried the land. As a rancher, he relied on a lush and healthy pasture. In spite of the promise of increased profit, he indicated his concern, both about using his own land for oil palm, and also having neighbouring farms plant this "thirsty crop" that he thought would "dry out" his property.

Social processes and variable access to opportunities

Despite the increasing array of lucrative livelihood opportunities in the region, many land managers and users faced barriers to adopting or even testing these opportunities. For example, in one community people indicated that most of the inhabitants practiced subsistence farming, with maize, beans, and small amounts of squash, peppers, and tomatoes. The vast majority (ca. 80 per cent) of the community held no cattle. The remaining 20 per cent of the population were ranchers with 20 to 40 animals, who sold heifers to regional buyers in Tabasco. Some land managers, and especially those with access to land, were able to start tree plantations, Farmers reported that the introduction of tree species dates back approximately ten years, when government programs distributed saplings. Of these trees, rubber (*hule*) is being sold, and commercialization of oil palm has begun. Other trees, farmers noted, are not yet profitable, highlighting the risk and delayed returns that farmers assume in planting the trees (versus using the land for cattle).

Many of these land uses in *ejidos*, *colónias*, and among largeholders are enabled or restricted by land tenure systems and access to capital, and several interviewees pointed out that little available land remained, making it difficult to expand holdings. For instance, much of the valley floor was cleared and under use, requiring farmers to expand up the steep hillsides at the border of the valley. Many farmers readily admitted that the steep slopes were not optimal for agriculture or ranching, yet they observed that there were few other options available. Further, many residents did not own land and were required to rent land or work on other farms.

In contrast to the struggles of landless and land-limited farmers, there were an increasing number of large landholders, with holdings in the hundreds to thousands of hectares, throughout the valley. One of the employees on a large teak plantation commented that the plantation owner had sought to purchase and consolidate the farms of several larger local landholders to muster sufficient hectares for a profitable teak plantation. This effort at land acquisition and ownership consolidation had varied impacts across *ejidos* and *colónias*

due to their different land tenure and decision-making arrangements.

Indeed, land tenure drove the power dynamics that affected the options available for livelihood diversification strategies. Table 2 provides a list of diversification strategies pursued by different land managers and farmers in the region, the limitations of the strategies, and the primary stakeholders who benefitted from these strategies. The most lucrative strategies, such as adding more profitable crops to one's agricultural portfolio and accessing government subsidies to create or expand agricultural holdings, were reserved for the large landholders who had the greatest access to information and could afford to take the most risks. Tree plantations, for example, require specialized knowledge about the cultivation of these species. They represent a long-term investment, and one subsequently supported by government subsidies that are most often provided directly to commercial entities.

Both smallholder farmers and those with somewhat more land identified ways to diversify their livelihood strategies, though these options were less lucrative and involved different types of risks. Many farmers, even those with limited assets, sought to maintain several potential income streams, so as to diversify their livelihood strategies in case one or more of these should be interrupted. One common strategy that farmers had pursued for decades involved increasing the number of their cattle. As described above, though, diminishing land access limited the farmers' potential to expand their holdings, forcing them to pay to rent land or use increasingly marginal land.

With fewer local options for agricultural diversification and expansion, some households pursued non-farm options, such as temporary migration or supplemental income opportunities. Some family members migrated to larger cities in Mexico, such as Puebla or Playa del Carmen, to find work in factories or the tourism business, or crossed into the United States. The goal behind such migration was not to relocate, but to work for several months or years and save money. That money could be used to address either immediate family needs (e.g. illness or schooling costs), or to make longer-term investments, such as purchasing a house or more land for cattle. Some households reported that temporary migration was financially beneficial for their families, and one man had purchased and opened a store in his community that was thriving. However, this same man also indicated that the migration was emotionally challenging, as he was separated from his family for several years.

Interestingly, migration options were typically most readily available to those with some assets: small or medium landholders. The landless reported that most were unable to migrate, because their absence would put too much of a strain on the family. Some opted for destinations requiring smaller capital investments, such as domestic migration to cities like Playa del Carmen or Puebla. Though less lucrative, domestic migration carried less risk than international migration and was commonly cited as a reliable short-term solution. For most landless and land-limited farmers, their wage labour options were typically limited to seeking supplemental employment on other farms or even in non-farm work. While this activity provided additional income, these jobs were typically short-term opportunities that were inconsistent and unstable. While diversifying the household's livelihood strategy, they did not provide a reliable source of income.

DISCUSSION AND CONCLUSIONS

Linking together the historical review, landscape change analysis, and individual interviews, this study demonstrates the diversification pathways impacting landscape changes and changing adaptive capacities in the Usumacinta Valley of Chiapas, as well as the implications of these changes.

Importantly, this research points to the complicated relationship between the capacity to adapt to changing conditions and diversification for different landholders. While previous research suggests that diversification can provide an important strategy for adapting to stressful circumstances (Ellis 1998, Steward 2007), results of this study indicate that access to the benefits of diversification varies by the scale of land access and ownership. Diversification can lead to livelihood atomization for the landless and smallholders, introducing new vulnerabilities and risks to their lives. In short, agricultural diversification benefitted large landholders, while livelihood diversification, characterized by risky and uncertain returns with limited governmental support, became a coping

TABLE 2 *Livelihood diversification options*

Diversification strategy	Limitations	Benefitting land managers/users
Adding more profitable crops to agricultural portfolio	Difficult to learn new cultivation techniques and markets; long-term investment; land intensive; requires initial capital.	Large land holders
Governmental subsidies or special programs	Limited or variable availability; access about subsidies is restricted	Large land holders; Small- to medium-holder farmers with clear legal land rights
Begin or increase cattle ranching	Necessitates purchase or rental of suitable land, which is increasingly scarce and/or expensive	Small- to medium-holder farmers
Temporary migration	Emotionally challenging; requires some initial capital; politically risky	Small- to medium-holder farmers
Supplemental employment	Seasonal and unstable opportunity; short-term solution	Landless/land limited

strategy for small to medium landholders. For instance, interviewees commonly cited the desire to use the land for a more economically profitable use or crop. While maize and beans provided subsistence, the potential benefits of tree plantations and cattle were enticing to many. Challenges arose due to uncertain returns on the longer-term investment and uneven access to information about subsidies and other incentive programs. Thus, differential access to opportunity was linked to cyclical land use and cover *swaps* versus lasting transitions to new land uses.

Interviewees mentioned numerous subsidies and rural support programs, though these were not always utilized to their fullest potential, or contained barriers to access for some landholders and the landless. The positive and negative impacts of many such programs have been discussed elsewhere (Klepeis and Vance 2003, Roy Chowdhury 2007, Radel *et al*. 2010). In this study, interviewees mentioned several new programs from both SAGARPA and CONAFOR as having potential to improve their economic situation and further transform the landscape. At the same time, particularly within the context of the tree plantation development, the availability of subsidies was limited to commercial entities rather than small-scale farmers. As the marginal input of labour and capital decreased for each additional head of cattle raised on the land, the desire to expand cattle stocks was cited as an ambition by those who already had cattle. While investment in cattle required more resources than other agricultural land uses, the markets were in place for more immediate returns. Similarly, diversification of economic opportunities might include seeking additional farming or ranching employment or temporary migration to domestic and international locations.

The landscape-scale evidence of these changes varied by the scale of the lands to which each type of actor had access. For the smallholders, the short-term diversification that served to bridge a period of challenges may be seen as the short-term swap in the composition of vegetation on the landscape. For medium- and large-landholders, landscape-scale diversification represented a deliberate transition from a previous to future landscape state, with no anticipated future swap. This specialization and, in some cases, consolidation of landscape activities introduced new types of land uses, adding to livelihood diversification, but also reducing the landscape heterogeneity in some contexts.

Overall, these varied solutions represented a range of options to the common challenge of a shifting economic situation and changing environmental conditions, similar to the findings of Batterbury (2001) and Saldaña-Zorrilla (2008). However, along the lines of McCabe and co-authors (2010), this study also revealed that these diversification opportunities reflect local and regional power dynamics, and represent different possibilities for the various land users in this region. Further, although investing in unrelated economic activities provided one way to cope with changing economic and environmental conditions, it also increased the workload and need to learn a new crop or trade and the associated market. Smallholder farmers might be able to add a more lucrative crop to complement their *milpa.* It was, however, a considerable investment to diversify to cattle, to expand plots, or to increase yields to produce crops for the market. However, should a smallholder migrate to earn income elsewhere, these new funds might enable the opportunity to purchase additional land for cattle or crops. The migrant could also invest in plantation crops, or open a store. The choice to invest in more profitable crops or to raise more cattle was one that was largely limited to those with enough resources (e.g., speculators from another state) and could undertake this investment risk. Those with little or no land were confined to seeking additional employment in an attempt to generate capital.

As proposed in the framework of McCusker and Carr (2006), the processes shaping both the physical landscapes of the Usumacinta Valley and the livelihoods and economic options of those who live and work there demonstrate a reciprocal connection in both their causes and effects. Results of the remotely sensed imagery analysis demonstrated that net losses in vegetative composition during this time period impacted a relatively minor fraction of the landscape. However, the perception of these changes and their implications for the use of the land were mentioned frequently in the interviews. Diversification of activities is seen through the substantial *swap* that has taken place over the last three decades, as lands transition in and out of use and the vegetation density fluctuates. Because this landscape has substantial water resources and experiences high annual rainfalls, regrowth in fallow or unused lands is rapid and dense, contributing to the apparent dynamism of the landscape evident in the analysis of the remotely sensed imagery. As numerous interviewees observed, the potential responses to these changing climatic and economic conditions involve several possibilities. Regardless of the methods, options for enhancing the adaptive capacity to anticipate or respond to such changes vary among actors and according to the scales of their assets and networks. Results of this study demonstrate multiple strategies used by residents of the Usumacinta Valley to manage these shifting risks and opportunities. Further research should extend the investigation of the implications of these current and speculative land use decisions on future conditions. The Usumacinta Valley continues to transition from a forested landscape to a post-frontier scenario, bringing new development possibilities. Differential availability of those options, based on access to land, capital, and government subsidies, is shaping the future opportunities and challenges that small- and largeholders will experience in this dynamic region, as well as their mark on the landscape.

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