PHYTOSOCIOLOGY, HISTORY AND DIVERSITY IN FARMER-MANAGED LANDSCAPES ON THE TONLE SAP FLOODPLAIN, CAMBODIA

by

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Abstract

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Adviser: Professor Christine Padoch

Driven by the annual flood pulse of the Tonle Sap Lake, the Tonle Sap floodplain in central Cambodia is a landscape characterized by dynamism, both ecological and social. Annual floods and rainfall vary in timing, duration and intensity from year to year. Patterns of burning, grazing, and agricultural expansion and contraction all leave their imprint on the landscape. While in the social domain, the region is likewise as complex. The genocidal, Maoist regime of Pol Pot darkened the 1970s. However, this was both preceded by, and followed by, years of civil war and social unrest. In recent years, Cambodia has shifted from a centrally-planned economy to a free-market economy, and experienced rapid economic growth followed by a dramatic slowdown. In the wake of such flux, the floodplains remain among the most productive rice-growing regions in the country, and are home to one of the most productive inland fisheries in the world. Even so, the region also remains one of the poorest. This project weaves analytical strands from ecology, geography and anthropology to delve into the ways in which people make a living in such a complex, challenging environment by focusing on the relationships between people, the landscape and plants. Results are presented from an analysis of 47 years of land use/land cover change depicted in aerial photography; an analysis of the structure and composition of floodplain plant communities through the use of descriptive ecological inventory; and an analysis of household-level natural resource-based livelihood activities, detailing how plant communities are utilized by village residents. A case study in floodplain land use is also presented, focusing on the Hillock-Depression Complex, a landscape element newly described herein. This case study illustrates the pitfalls of top-down land use planning in the context of a landscape rich in resources important to local residents but illegible to policy-makers. The results of these diverse analytical streams suggest that people do not live on the floodplain in spite of tremendous dynamism. Rather, the opposite is true. They live on the floodplain because of such dynamism, not as passive subjects but as active agents in generating diversity.

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Of course, any errors remain exclusively my own.

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Chapter 1

Introduction: The Diversity of Dynamism(s) of the Tonle Sap Floodplain

> *"...The country, for nearly 100 miles around [Battambang], is flooded with water soon after the commencement of the rains; traveling becomes impossible, except in boats, and wild animals are driven off to the mountains..."*
>
> – D.O. King's 1860 report to the Royal Geographic Society of London, Travels *in Siam and Cambodia*.

> *“...The flood of 2000/01, considered the worst in 70 years, affected 3.4 million people [on the Tonle Sap floodplain]. The flood of 2001/02 affected 2.1 million people in regions still recovering from the deluge of the previous year. The drought of 2002/03, reported by the government as the worst in two decades, affected more than 2 million people. The drought of 2003/04 caused lakes in the deepest part of the floodplain to dry out. The drought of 2004/05 affected 2 million people and resulted in widespread food shortages..."*
>
> – Sopha et al. 2007 in reference to the Tonle Sap Floodplain.

មានទឹក មានត្រី មានដី មានស្រូវ ៗ

"When there is water, there is fish; when there is land, there is rice."

-- Khmer proverb.

Biophysical Dynamism of the Tonle Sap

The floodplains of the Tonle Sap are a dramatic landscape. With the ebb and flow of floodpulse and tropical monsoons, it is perpetually in a state of transition between aquatic and terrestrial phases. Though this pendulum swings with annual regularity, from year to year there is great variation in flood timing, rate, height, and duration.

Rainfall exhibits similar inter-annual variation. This degree of dynamism selects for a particular suite of organisms able to both take advantage of windows of opportunity, as well as minimize losses during windows of phenological vulnerability (Wantzen et al. 2008). The same holds true for the people who make their livings on the floodplain. A diverse portfolio of livelihoods taking advantage of a variety of plant communities offers the most flexibility, and as such, the most household stability (Mortimore and Adams 2001, Adams and Mortimore 1997). As Sopha et al. (2007) allude to in the quotation at the beginning of this chapter, even the most flexible households may be unable to adapt when the pendulum swings beyond the norm. Despite such environmental flux, indeed likely because of it, the Tonle Sap floodplain is both the highest yielding rice producing area in Cambodia as well as one of the most productive inland fisheries in the world, with over 235,000 tons per year harvested (van Zalinge 2002).

Believed to have been formed 5000-7000 years ago,[1] the Tonle Sap Lake and its 80,000 km^2 watershed (nearly half of the total area of the country) drain into the Mekong River by way of the Tonle Sap River (Campbell et al. 2006). The rivers join at the capital, Phnom Penh. Towards the end of the rainy season, as the Mekong River swells to its peak with water draining from as far away as Tibet, Yunnan and Laos, the Tonle Sap River reverses direction and backs-up into the Tonle Sap Lake (Figures 1a and 1b). The lake acts as a reservoir for the Mekong, mediating flooding further downstream along the banks of the Mekong River. In buffering this flooding, the Tonle Sap swells

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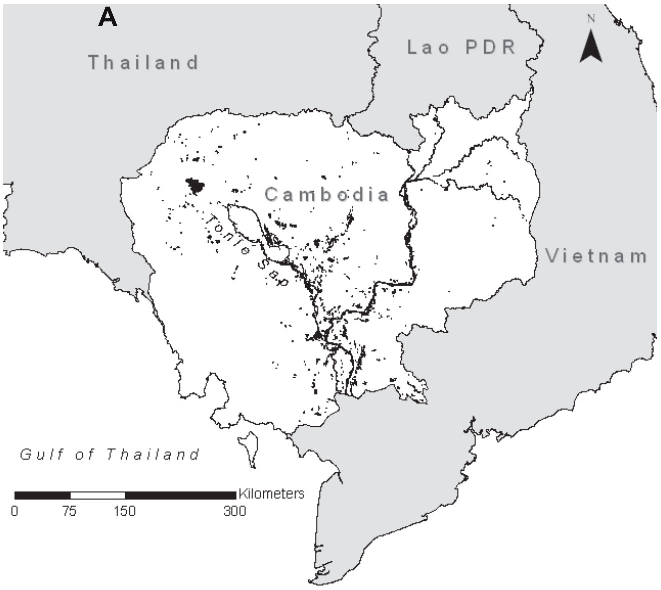
[1] For an alternative view on the origin of the Tonle Sap see Hartung and Koeberl (1994), who suggest that the Tonle Sap Lake is a crater resulting from a meteorite impact.



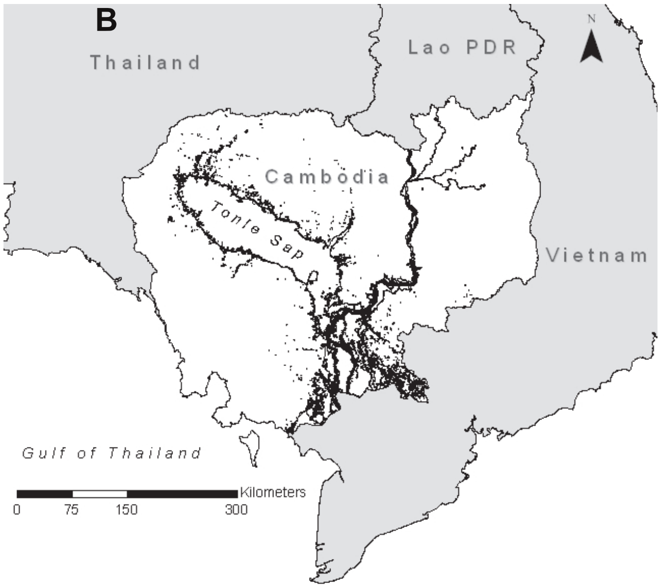


Figure 1. Regional map indicating Tonle Sap Lake margin. A. Dry season margin (data dating from March 1999, source: Tonle Sap Environmental Management Program/Fisheries Administration); B. Wet season margin (data dating from October 2000, source: Tonle Sap Environmental Management Program/Fisheries Administration).

from a dry season area of about 2500 km^2 to a wet season peak about 13000 km^2, varying from year to year. Likewise average depth of the lake jumps from 2 m during the dry season, to 8-10 m at the height of the flood (Hak and Piseth 1999). This influx of water brings with it sediments which are deposited largely in the flooding forest and on the floodplain near the lake margin (Kummu et al. 2008). The aquatic and terrestrial phases of the landscape are connected by other channels as well, including flows of carbon and nutrients from the terrestrial to the aquatic through the breakdown of terrestrial organic matter with the arrival of the floods, and also the stranding and subsequent decay of periphyton, algae and aquatic macrophytes as the floods recede. The density of these connections between the terrestrial and aquatic account for the high productivity of this system (Hand 2002, Junk and Wantzen 2004, Wantzen et al. 2008).

Floodwater from the Mekong River accounts for just over half of the water filling the Tonle Sap as it expands beyond its dry season margins. The remainder is inflow from tributaries (30%) and precipitation (13%) (Kummu et al. 2006). Rains usually begin in earnest in May, heralding the arrival of warm, wet weather associated with the Southeast Monsoon. Rain falls nearly daily until October, dropping an average of 1550 mm per year in Kampong Thom (Davidson 2006).

There is sometimes a dry spell during the rainy season of up to few weeks in duration. The duration and timing of this dry spell vary from year to year. But the timing in particular, can have serious implications for farmers. An early onset, while rice crops are still immature, can lead to stunting at best, or the loss of a crop at worst. The tapering of the rains in October signals a shift to the cool, dry season of the Northeast Monsoon. Over the course of the year, temperatures fluctuate from the low to mid-20s °C early in the dry season, climbing to the low to mid-30s °C as the dry season grades into the wet season. Temperatures peak in April, just before the onset of the rainy season. Annual fluctuations, from wet to dry, and from cool to hot has led to distinctive plant communities on the floodplain.

Plant Communities of the Floodplain

Floodplain plant species are organized into a handful of plant communities, the most characteristic of which are the flooding forests and the flooding savannas. Fringing the dry season margin of the Tonle Sap lake are flooding forests, termed *forêt inondee* by Rollet (1972), and swamp forest or stunted swamp forest by Rundel (2009). Much of these communities are flooded by 4-6 m of water for up to 8 months per year, though some areas are permanently inundated swamps. Dominated by *Barringtonia acutangula* and *Diospyros cambodiana*, this 7-10 m canopy forest is unlike other flooding or swamp forests in Southeast Asia (Rundel 2009). Trees lack pneumatophores, and palms and vascular epiphytes are notably absent (Rollet 1972). Lianas and herbaceous vines are common (Campbell 2006). Most of the woody species found in these communities are deciduous, dropping their leaves with the rising of the flood waters. Leaf-out coincides with flood recession. Flowering peaks during the rainy season in July or August. The seeds of many species are dispersed by floodwater and fish which enter the forests from the Mekong River to spawn (Rundel 2009, Campbell et al. 2006).

Fingerlings spawned in the flooding forest make their way onto the surrounding savannas to feed and mature, before returning to the Mekong with the draining floodwater in December and January. Stretching between flooding forests at the Tonle Sap shore and the uplands at the edge of the floodplain, the savannas are a mosaic of grasslands, shrublands and rice fields. They are heavily utilized by the communities that ring the distal perimeter of the floodplains. Savanna woodlands 2-4 m in height are dominated by the Euphorbiaceae, Combretaceae and Fabaceae (McDonald et al. 1997); while, understory and grassland communities are dominated by a number of grasses and sedges from 1-3 m in height (Chapter 3). The savannas are punctuated by low hillocks with their own particular floristic associations and land uses (Chapter 5). Similarly, permanent and seasonal ponds are scattered throughout the landscape, pockets of low-lying ground marked by plant communities with affinities to those more commonly found along watercourses and lakes.

Cambodia's Socio-Political Dynamism

As the Tonle Sap floodplain is ecologically dynamic, so too is the political-economic situation of Cambodia. Within the memory of the oldest residents of floodplain villages, Cambodia has seen five different national flags and over 30 years of war and civil unrest. Cambodia's economy has shifted from a centrally-planned to a market economy, expanding and contracting rapidly in recent years. These changes in political and economic structure have brought many changes to the lives of floodplain residents: civil war and the US bombing campaign of the early 1970s, the genocidal Maoist regime of Pol Pot from 1975-79, the famine of 1979-80, centrally-planned communal farming under the Vietnamese-backed regime from 1979-89, to a UN-enforced democratic election in 1994 that was followed in 1997 by a *coup de force*. Some areas of the country remained under the control of the Khmer Rouge, and in a state of civil war, as late as 1999.

Recent years have seen rapid expansion of the now free-market economy, particularly in the tourism and garment manufacturing sectors. Such employment contributes to livelihood flexibility by providing opportunities for non-farm work for rural families, and tightening connections between the urban and the rural (Rigg 2006). However, this rapid growth has been followed by an economic contraction starting in 2006 with the 2005 expiration of favorable trade quotas for textiles. This was followed in subsequent years by the H1N1 scare, political instability in Thailand and the global economic slow-down which all took their toll on tourism (United Nations Country Team: Cambodia 2009). With 20-30% of workers in the garment, tourism and other sectors out of work since 2008, rural families suffer as remittance income valued at between USD 30-40 million per year is also lost (United Nations Country Team: Cambodia 2009). Despite the ecological richness that characterizes the Tonle Sap, the floodplain remains one of the poorest regions in Cambodia (Varis 2008).

Orientation to the Study Site

The focal point of this research project was Roka Village (in Sangkat Srayov, Steung Sen Municipality, Kampong Thom Province, at 12° 37' N 104° 55' E), a village of approximately 500 families on an old alluvial terrace jutting out from the edge of the Tonle Sap floodplain (White et al. 1997). The village lies between 10 m and 15 m above sea level (asl), and gradually slopes down on 3 sides to meet the surrounding annually flooding rice fields and grasslands at approximately 10 m asl. It is connected to National Road 6, the paved road running between Phnom Penh and Siem Reap, by 4 km of improved dirt road (Figure 2).

The boundaries of the study area were selected based on preliminary interviews with Roka residents to incorporate as much of the land utilized by village residents as possible. As a result, study boundaries do not exactly follow administrative boundaries. Rather they more closely follow natural features. The northern boundary of the study area is the administrative border between Roka and Kamraeng Villages.

To the east and south, the area is bounded by the Steung Slap (or sometimes Steung Damrei Slap), a river flowing from north to south, eventually turning to the west. West of the village, the boundary follows the dirt road which runs from the village southwest. The boundary ultimately turns due south, passing to the west of Toul Kok Preah. The area forms a rough right triangle of approximately 122 km^2. The vast majority of the area lies within Sangkat Srayov, Steung Sen Municipality, Kampong Thom Province. A

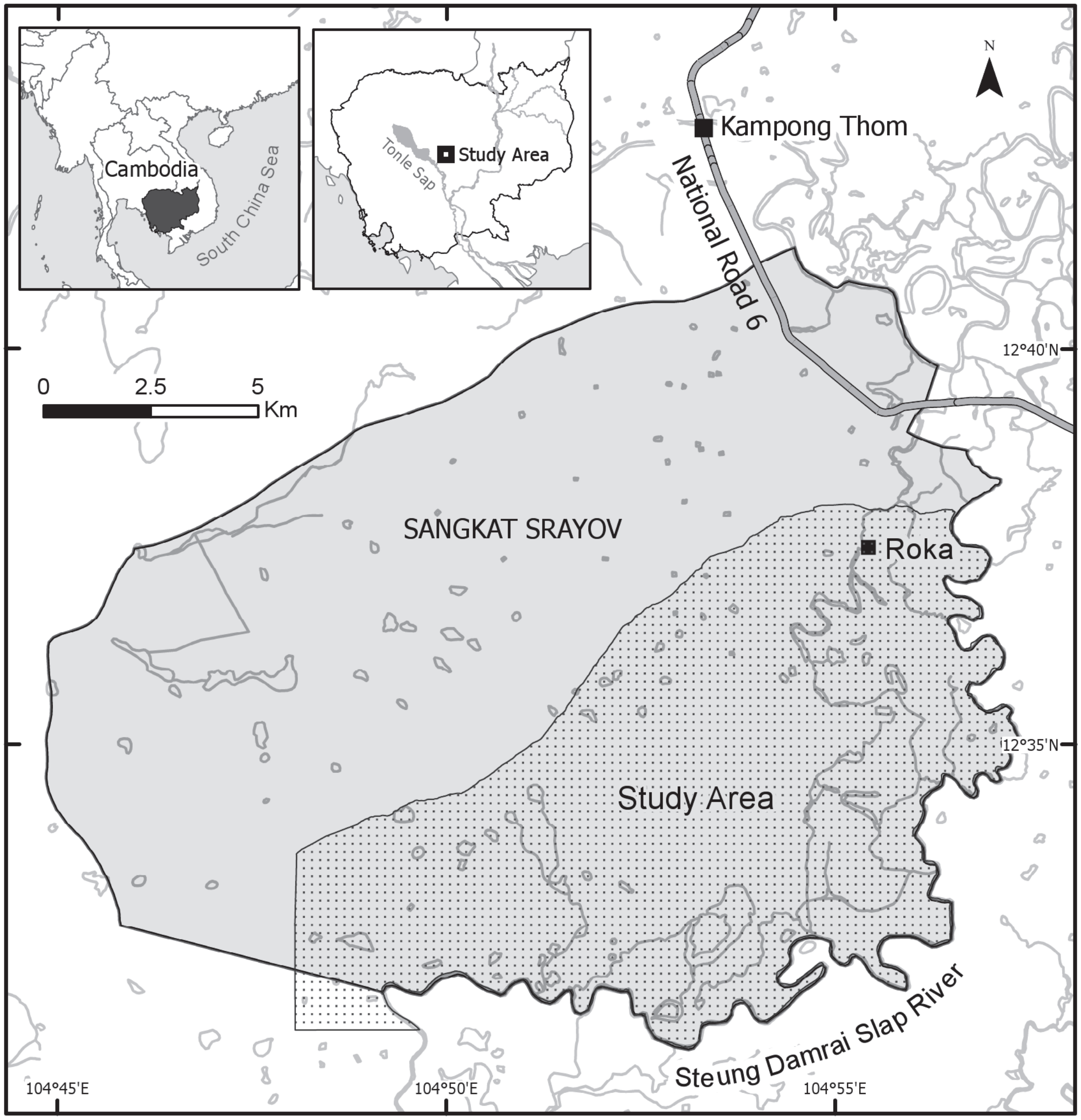


Figure 2. Map showing the location of the study area, 122 km^2 south of Roka Village (in Sangkat Srayov, Steung Sen Municipality, Kampong Thom Province). Sangkat Srayov is shaded gray, while the area of the study site itself is stippled.

small portion in the southwest strays into Kampong Chhnang Province at Toul Kok Preah.

Families in Roka village engage in a wide range of livelihood activities, the most common being rice production, fishing and keeping livestock (cattle and buffalo). In addition to natural resource-based activities, many families also include off-farm and non-farm activities in their livelihood portfolios. Such activities include retail sales, wholesale buying and selling ("middlemen"), engagement in a skilled trade, wage labor (often in the agricultural sector), producing value-added products (such as distilled liquor) and engagement as a ritual specialist. Few families specialize in any one activity; instead they spread their efforts among various endeavors depending upon the time of year (Figure 3). As will be discussed in Chapter 4, these activities are not only partitioned temporally, but spatially as well. Households engage in different activities in different areas, exploiting different plant communities. The resultant livelihood diversity brings flexibility and security, but it is dependent upon landscape diversity.

Plan of the Present Work

What follows is an exploration of this relationship between people and the landscape by investigating how people shape plant communities and how people are likewise shaped by plant communities. To accomplish this task, an interdisciplinary approach is used to: define the landscape in terms of plant communities, characterize these communities and how their spatial relationships have changed over time, characterize the natural resource-based livelihood portfolios of people who utilize these plant communities and,

Figure 3. Calendar of major livelihood activities and seasons. Gray bars denote the months when each activity is most commonly engaged in. A lighter shade of gray is used to show transitions. A darker shade of gray is used to mark the dry season fishery. While fishing takes place year-round, the dry season is the period of most intense fishing effort. The relationships between livelihood activities and plant community composition is discussed in Chapter 3, while the separation of livelihood activities in time and space is discussed in Chapter 4.

lastly, to elucidate the relationships between livelihoods and landscapes. Each of these topics takes the form of a chapter. Some of these chapters were prepared as free-standing articles for publication in peer-reviewed journals (Chapters 2 and 5). Others have yet to be prepared for publication (Chapters 1, 3, 4, and 6). As a result of this structure, each chapter contains its own topical literature review.

Chapter 1 serves as a brief introduction to the Tonle Sap floodplain and the bio-physical and social processes which shape it. It also introduces the study site and maps out the remainder of the dissertation.

Chapter 2 defines the landscape in the context of historical land use/land cover change by comparing a time-series of aerial photographs of the landscape dating from 1958, 1994 and 2005. Land use/land cover change data are presented and compared, and land use/land cover trajectories are analyzed. Each of the subsequent chapters is organized around the land use/land cover classification scheme developed in this chapter.

Chapter 3 presents the basic phytosociology of the floodplain flora based on data collected in an ecological inventory. The land use/land cover classes developed in Chapter 2 are characterized according to the plant species associations of which they are composed. Additionally, the effects of present day and historical land use on plant communities are discussed.

Chapter 4 explores how different plant communities are utilized by households in Roka Village. The results of household surveys designed to collect data regarding land use and natural resource-based livelihood activities for each land use/land cover class are presented and analyzed, and the relationships between livelihood diversity and landscape diversity are detailed.

Chapter 5 presents the Hillock-Depression Complex as a case study in floodplain land use and topographic diversity. The Hillock-Depression Complex is described, and the particularities of the temporal partitioning of livelihood activities centered around this feature are discussed. Landscape legibility and its importance in floodplain development planning is explored. Many floodplain livelihood activities have light footprints. Leaving little sign, they remain illegible to policy makers. This illegibility has led to a lack of equity in access to natural resources, as the needs of floodplain residents are overlooked or undervalued.[2]

Chapter 6 ties together these disparate disciplinary strands in a synthesis and conclusion which focuses on the cross-cutting theme of scale and how livelihoods and landscapes are themselves products of one another.

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[2] An earlier version of this chapter was awarded the 2010 Student Paper Award by the Culture and Political Ecology Specialty Group of the Association of American Geographers.

Chapter 2

Production System Change Through the Lens of Landscape Trajectories

ចុះទឹកក្រពើរ ឡើងលើខ្លា ៗ

Go down to the water, crocodiles. Go up [onto land], tigers.
– Khmer proverb

Theoretical Approach

Falling under the broad rubric of Political Ecology, hybrid methodologies have been used in a number of studies to historicize landscape and explore land use/land cover (LULC) dynamics (Birch-Thomsen et al. 2010, Reenberg et al. 2008, Arce-Nazario 2007, Thongmanivong et al. 2005, Klepeis and Turner 2001, Gray 1999, Fairhead and Leach 1996). Such studies “judiciously and eclectically” (Scoones 1999:491) intertwine methodologies from ecology and anthropology, with oral history, archival research and the collection of other secondary data in order to build an understanding of land use dynamics that is focused on the local, but also engages with extra-local actors and the agency of bio-physical factors in the landscape (Batterbury and Bebbington 1999, Scoones 1999, Batterbury et al. 1997).

Building on in this hybrid lineage, this paper details the results of an analysis of 47 years of landscape history and dynamics on the Tonle Sap floodplain in central Cambodia by interweaving land use/land cover trajectory analysis with landscape ecological and oral historical approaches, in order to better contextualize landscape change. Taken together, these approaches yield a more holistic, multi-scalar view of LULC change. A case study is also presented for one site within the study which corresponded to a single landscape trajectory, marking the appearance of an agricultural production system in a place where it had not been used in the recent past. The appearance of this production system is the confluence of the history and ecology of the study site, as well as the socio-political conditions in Cambodia in the late 1990s. It is an example of how landscape dynamics are the result of on-going, complex, multi-scalar ecological and social processes which are impossible to grasp using from-to analysis of LULC change alone.

There have been a handful of studies that have examined the relationship between Cambodia's complex history, both social and ecological, and the rural landscapes where the majority of the Cambodia's population lives. LeBillion (2000) detailed the political ecology of forests during the civil war. While others have discussed the abandonment of deep-water rice production during the civil war and Khmer Rouge regime, and its relationship to endangered bird habitat (Evans et al., 2005) and crop genetic resources (Sokha et al. 2002). While Fox et al. (2008, Fox 2002) detailed changes in land tenure and the drivers of LULC change in ethnic minority communities in the upland province of Ratanikiri. A number of archaeological studies have been performed at Angkor Wat, a UNESCO World Heritage Site in Siem Reap Province, examining ancient landscapes and environments of the Khmer Empire of the 9th to 11th Centuries (Evans et al. 2007, Penny et al. 2007, Buckley et al. 2010). These studies, as others elsewhere, have shown that the landscape, as a component in a coupled human-environment system

(Turner et al. 2007), is constantly in flux in relationship to both local actors as well as processes operating at different hierarchical scales of biological and social organization (Lambin et al. 2003).

Like the landscape, farming systems too are constantly in flux (Padoch et al. 2008). In the same way that remotely sensed imagery can give us snapshots of the landscape at different points in time, and allow us to build hypotheses about landscape history or even landscape possible-futures, so too does remotely sensed imagery present a snapshot of farming systems that were in use at the time that the image was taken. In some cases, the systems active in older imagery are no longer in use in the present day. In others, it is possible to find continuity. Sometimes both are evident. Such is the case with the aerial photography analyzed for this study. Over the timespan of these images (1958-2005), a new rice production system appears. As Turner and Brush (1987:11) point out, “...differences between agricultural systems also denote fundamental differences between social and economic systems.” The flux in agricultural systems evident in the imagery is thus evidence not just of ecological flux but also flux in Cambodia's social and economic systems, and the different configurations of technology and labor organization at the local level.

Sometimes flux in production systems is obvious to the outside observer as it results in a systematic change in how production occurs, shifting from one production system to another with investments in landesque capital (Blaikie and Brookfield 1987) and other changes being made all at one time (Doolittle 1984). In other cases, the changes may be more subtle as the farmer tinkers with his or her approach, making adjustments to management or labor organization based on innovations, prior experience, personal preference and new information from others (Brookfield 2001). Lastly, a system in flux may present itself to outside observers as messy or chaotic, the directionality of its change illegible (Doolittle 1984, 2001; Padoch et al 1998).[3]

While LULC trajectory is sometimes used to refer to a narrative description of LULC change over time (e.g. Moran et al. 2001), it also may be quantified using remotely sensed data by analyzing the number and nature of category changes in a georeferenced unit of study, be it pixel, patch or parcel, over a time series of images. Singled out recently as being especially useful in identifying rates of change and emergence of system structure (Dearing et al. 2010), Mertens and Lambin (2000) were among the first to use LULC trajectory analysis in their study of forest change in Cameroon. Crews-Meyer (2002, 2004, 2006) also used this approach in a landscape ecological context. She traces the history of this approach to the “panel analysis” or “longitudinal analysis” used in quantitative sociology (Crews-Meyer 2006).[4] Other studies have used this approach to include multi-variate analysis of socio-economic data or land ownership in West Africa (Braimoh and Vlek 2005; Reenberg 1999, 2001), and North America (Proulx and Fahrig 2010; Ruiz and Domon 2009). While all of these studies address in some way the spatio-temporal aspects of LULC change, none

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[3] In putting conceptual boundaries around multiple production system processes constantly in flux, we are in danger of reifying a "*system*", in actuality one configuration of technology, knowledge, labor, biotic and abiotic factors, as being something tangible rather than a convenient unit of reference and analysis. For the purposes of this analysis, Brookfield et al.'s (2002) “land use stage” is taken as the definition of "production system." They define land use stage as, "areas of broadly common ecology, land use (or its absence), and especially recent land use history" (Brookfield et al., 2002:41). For a related, though critical view, see Vayda et al.'s (1991) discussion of the pitfalls of the reification of *process*.

[4] For more on panel analysis, see Rindfuss, et al. 1987.

incorporate the narrative experiences of local actors through oral histories. Further, save for Crews-Meyer (2002, 2004, 2006), none have used landscape ecological tools to describe the structural element of landscape change.

Analysis of landscape trajectories is one method of quantifying the *temporal* element of landscape change over time. However, it does not capture the change in overall landscape *pattern*. Emphasizing the relationships between landscape spatial configuration and ecological processes, tools of landscape ecology are well suited to address this problem (Turner 1989). Here, landscape ecological indices are used to quantify the degree of human management of the landscape through the expansion of agriculture.

On the Tonle Sap floodplain in Kampong Thom, rice fields are relatively rectangular or polygonal, forming a reticulate landscape. Straight field boundaries are contrasted with the irregular boundaries of patches of non-agricultural plant communities. Likewise, a mature rice or grassland landscape is relatively homogeneous, in contrast to the intermingled matrix of grassland and rice fields found at the interface of these communities where agriculture may be expanding (referred to here as the rice field-grassland frontier).

While analysis of LULC trajectory change and changes in landscape spatial pattern are valuable in developing an understanding of LULC dynamics, they do not explain the *lived* aspects of the landscape-- the landscape as a place where people not only make changes in land use or land cover, but also live out their lives. While many studies complement remote sensing analysis with on-the-ground fieldwork, comparatively few explicitly utilize oral history (for Amazonia, Arce-Nazario 2009; for Africa, Börjeson 2007, Gray 1999, Fairhead and Leach 1996, Cross and Barker 1991; for South Asia Skaria, 1999). Oral histories are utilized here not just as a sort of “ethnobotanical ground-truthing” (Shepard et al. 2004) but to contextualize the temporal and spatial patterns of LULC change elucidated using the above methods.[5]

Regional Background

King (1860:179), in a narrative of an overland journey through Thailand and Cambodia, described the area around the Tonle Sap in central Cambodia as “...pleasantly diversified with forest and open prairie...” Far from this bucolic imagery, the Tonle Sap floodplain is actually as dynamic as it is productive. Driven by an annual flood pulse (Junk 1997), it is the largest wetland in peninsular Southeast Asia. Most of the year, it drains into the Mekong River via the Tonle Sap River. However, at the peak of the annual humid southwestern monsoon season, the flow of the Tonle Sap River reverses direction, bringing water, fish and sediment into the Tonle Sap from the Mekong River. This causes the Tonle Sap to swell from a dry season area of approximately 2500 km^2 to 13,000 km^2 or more at the peak of the annual flood, deepening from 2 m to 8-10 m in the same timeframe (Figures 1a and 1b)(Hak and Piseth 1999). While mediating flooding on the lower Mekong floodplain, the Tonle Sap floods the fringe of forest which surrounds the lake and flows onto the savannas beyond, changing the floodplain's terrestrial landscape to an aquatic landscape for as long as 5 months per year (Hak and

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[5] See also Doolittle 2006:195 for comments on the challenges of using oral history to understand LULC change.

Piseth 1999).

Even as intra-annual dynamism is high, so too is inter-annual dynamism. The height and timing of the flood vary year-to-year, as does the amount of local rainfall and flooding due to run-off from nearby uplands. This ecological dynamism drives a very productive ecosystem, as the Tonle Sap floodplain is both the highest yielding rice producing area in Cambodia as well as one of the most productive inland fisheries in the world, with over 235,000 tons per year harvested (van Zalinge 2002).[6] However, despite this ecological richness the Tonle Sap floodplain remains one of the poorest regions in Cambodia (Varis 2008).

While the Tonle Sap floodplain is ecologically dynamic, so too is the political-economic situation of Cambodia. Within the memory of the oldest residents of floodplain villages, Cambodia has seen five different national flags and over 30 years of war and civil unrest. Cambodia's economy has shifted from a centrally planned to a market economy, expanding and contracting rapidly in recent years. These changes in political and economic structure have brought many changes to the lives of floodplain residents, from civil war and the US bombing campaign of the early 1970s, the genocidal Maoist regime of Pol Pot from 1975-79, the famine of 1979-80, centrally-planned communal farming under the Vietnamese-backed regime from 1979-89 to a UN-enforced democratic election in 1994 which was followed in 1997 by a *coup de force*. Recent years saw rapid expansion of the now free-market economy, particularly in the tourist

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[6] See van Zalinge 2002 and Lamberts 2006 for reviews of the many productivity estimates of the Tonle Sap fisheries, and the difficulties with measuring them.

and garment manufacturing sectors. Such employment provides opportunities for non-farm work for rural families, tightening connections between the urban and the rural (Rigg 2006). However, this has been followed by an economic contraction, starting in 2006 with the 2005 expiration of favorable trade quotas for textiles. Subsequent years saw the the H1N1 scare, political instability in Thailand and the global economic slow-down, which all took their toll on tourism (United Nations Country Team: Cambodia 2009). With 20-30% of workers in the garment, tourism and other sectors out of work since 2008, rural families suffer as remittance income valued at between USD 30-40 million per year is also lost (United Nations Country Team: Cambodia 2009).

Research Site

The focal point of this research project was Roka Village (in Sangkat Srayov, Steung Sen Municipality, Kampong Thom Province, at 12° 37' N 104° 55' E), a village of approximately 500 families on an old alluvial terrace jutting out from the edge of the Tonle Sap floodplain (White et al. 1997). The village lies between 10 m and 15 m asl, and gradually slopes down on 3 sides to meet the surrounding annually flooding rice fields and grasslands at approximately 10m asl. It is connected to National Road 6, the paved road running between Phnom Penh and Siem Reap, by 4 km of improved dirt road (Figure 2).

The boundaries of the study area were selected based on preliminary interviews with Roka residents in order to incorporate as much of the land utilized by village residents as possible. As a result, study boundaries do not exactly follow administrative boundaries. Rather they more closely follow natural features. The northern boundary of the study area is the administrative border between Roka and Kamraeng Villages. To the east and south, the area is bounded by the Steung Slap (or sometimes Steung Damrei Slap), a river flowing from north to south, eventually turning to the west. West of the village, the boundary follows the dirt road which runs from the village southwest. The boundary ultimately turns due south, passing to the west of Toul Kok Preah. The area forms a rough right triangle of approximately 122 km^2.

The vast majority of the area lies within Sangkat Srayov, Steung Sen Municipality, Kampong Thom Province; though, a small portion in the southwest strays into Kampong Chhnang Province at Toul Kok Preah.

Some village residents travel beyond the borders delineated for this study to fish, tend livestock or collect fodder and firewood. However, such trips are not common. The daily activities of most village residents fall within the study boundaries.

Methodology

Data used in this study were collected over the course of three periods of village-based research: May 2007-December 2007; March-June 2008 and January-May 2009. A range of methodologies was used, embracing an interdisciplinary approach integrating methods from the fields of geography, ecology and anthropology in order to explore land use and human ecology (Brookfield et al. 2002, Cunningham 2001, Alexiades 1996, Scoones et al. 1994). These methods included semi-structured interviews with key informants (village elders and other local experts, but also including ministerial officers, local extension officers and employees of international development NGOs); field walks with key informants; unstructured interviews with village residents; written surveys focusing on land use (administered to 238 families, nearly 50% of the households in village) and participant-observation, joining village residents in their farming, fishing and livestock-keeping activities. A descriptive ecological inventory of floodplain vegetation was also performed (60 transects of 1000 m^2 each).

Land Use/Land Cover Classification

For the analysis of LULC change over time, three sets of georeferenced, ortho-rectified aerial photographs were procured from the Cambodian government's Department of Geography. These image sets dated from 1958, 1992 and 2005. The exact dates on which the images were taken is not known, though all were taken during the dry season, after the annual floods had receded (December or January). The two earlier sets were black and white, scanned from the original photographs at 600 dpi, while the 2005 images were a color, digital product. The scales from the images ranged from 1:40,000 (1958) to 1:25,000 (1992, 2005). These images were manually classified into land use/land cover categorical maps using ESRI's ArcGIS 9.3 and extensions. Classification of all three data sets was performed by the same analyst to minimize error. The minimum mapping unit was 10m x 10m. Cloud cover was absent from the 1958 and 2005 images, but made up 0.9% of the 1992 image. This area was masked in all three images so that it would be omitted from further analysis in order to maintain comparability between images. The polygon LULC maps were then imported into winGRASS (GRASS Development Team 2010) and converted into rasters for LULC change trajectory analysis. Landscape ecological analyses of rasterized versions of the LULC maps were performed using the IAN image analysis program (DeZonia and Mladenoff 2004).

The LULC analysis of the orthophotos utilized 7 relatively broad classes: shrubland, grassland, hillock, ricefield, settlement, river and waterbodies. The definitions of the classes were chosen based on three factors. First, 8 is the greatest number of classes which can be reliably discerned in the lowest resolution orthophoto. Second, these categories roughly match the local categories used to describe these cover types. Finally, limitations on computing power capped pixel bit-depth at one byte for the calculation of landscape ecological indices (Crews-Meyer 2006). A raster with more than 9 class values would have necessitated a different bit-depth, rendering computation prohibitively intensive.

The classification was designed to capture inter-year, as opposed to intra-year, variation (Crews-Meyer 2004). Thus classes with intra-year variation, particularly rice fields, were categorized by their dominant, terrestrial LULC regardless of time of year. For example, areas used for growing rice were classified as "rice field" whether or not there was a standing rice crop in the field at the time the image was taken. For such a dynamic landscape, LULC categories are somewhat arbitrary, based on the time frame of interest and the timing of the image with respect to the annual flood. For example, any rice field might also be classified as a pasture, depending upon what time of year it is observed. Further, the entire landscape, save the hillocks, is submerged at the peak of the annual flooding, thereby allowing for hillocks to be potentially classified as islands. Additionally, as the floods receded, floodplain depressions trap water forming ponds. These ponds will vary in area depending upon when they are measured, with variability dependent upon when the flood recedes and upon local evaporation/infiltration rates. This complexity adds some fuzziness to comparisons of LULC category measurements over time, as variation in one class will be associated with variation in one or more other classes. In other words, some inter-annual changes in the areal extent of LULC classes such as grasslands and rice fields might be due to variation in pond size. The LULC categories chosen therefore speak to the central questions to the study, as do the LULC change trajectories chosen for this discussion (Walters and Vayda 2009)**.**

Class Descriptions

Shrubland: This category includes areas dominated by woody vegetation. This vegetation comprises a range of communities and densities, from dense riparian forest to flooding shrubland and heavily coppiced forest or shrubby remnants. It does not include the woody vegetation found atop hillocks, which is a different plant community from other woody environments. The forested areas in and around settlements were not included in this category.

Grassland: This category includes areas dominated by herbaceous vegetation, either grasses or sedges. These environments may include solitary trees or sparse, open woodland with a herbaceous understory. This class includes the various savanna communities (short grass and long grass, (Davidson 2005) found on the floodplain.

Hillock: This category comprises low hillocks which pepper the floodplain landscape, likely the remnants of ancient alluvial terraces or river meanders (White et al. 1997, Delvert 1994 [1961]). These hillocks occasionally feature small built structures for seasonal habitation. Vegetation varies, from grassy cover without trees, to sparse woodland, to dense tree and shrub cover. Many hillocks seldom, if ever, flood. As a result, some plant species are found atop hillocks that are not found elsewhere on the floodplain.

Ricefield: This category aggregates all of the areas used for rice production, regardless of production system. It also includes areas which were used for rice production within the last 2 or 3 years. These may represent fields which are brought in and out of production on a year to year basis, depending upon the needs and labor availability of the land owners. Individual rice fields many not be in cultivation every year, but the area remains a rice production space. Any fields abandoned for a longer period, evident by the degree of grassy or woody encroachment, were categorized as grasslands or shrubland, respectively.

Settlements: This category was used for areas which were used for permanent settlement, evident by the numbers and densities of built structures, as well as patterns of planted trees. These areas are usually atop hillocks and are wooded to some degree. The forest associated with settlements is also included in this category.

River: This class is used for the Steung Slap, which borders the study site to the East and to the South. In the orthophotos, the river was obscured in some places by riparian forest along the river margins. This is reflected in the discontinuities in the path of the river.

Waterbodies: This class includes all waterbodies found within the study area, excluding the Steung Slap. It includes a wide range of waterbodies, from small streams and creeks to seasonal and permanent ponds, as well as large permanent lakes.

Land Use Change Analysis

In ArcGIS (ESRI 1999-2008), categorical LULC map classes were coded to reflect both the year of the map and the LULC category. For example, the grasslands category on the 1958 map was coded "3", while the same category on the 1992 map was coded "300." To elucidate landscape trajectories, the three LULC maps were summed using a raster calculator (winGRASS's *r.mapcalc*), with the results output to a fourth raster. Each category consisted of a numeric value which represented the sum of the three LULC codes from the maps. The values for categories in this raster contained a numerical code corresponding to the “life history” of each pixel, or its LULC trajectory (Crews-Meyer 2004). This value is readily translated into a series of LULC values, their sequence representing change over time. For example, pixels in category "5503" were classified as grassland on the 1958 image, ricefield on the 1992 image, and ricefield on the 2005 image.

Landscape Ecological Analysis

To quantify differences in landscape structure between the maps, landscape ecological indices measuring landscape diversity (Shannon diversity), patch perimeter shape (fractal dimension and area-weighted perimeter-area ratio) and texture, or the interspersion of categories (contagion) were calculated using IAN image processing software (DeZonia and Mladenoff 2004). These indices were chosen because they were most relevant to the study questions and capture much of the variation between landscapes with little redundancy (Li et al. 2005, Turner et al. 1989, Turner et al. 2003, Riitters et al. 1995).

Results

LULC Change Over Time: Area and Percent Cover

The areal and percent cover for each LULC category of each map is summarized below (Table 1 and Figure 4, respectively). However for the purposes of this study, only the change in four LULC categories will be considered: Shrubland, Grassland, Ricefield and Settlement. The areal change of hillocks is not considered here. As relatively static geomorphological features, they are expected to change little over the study timeframe. The difference in hillock area between years is due to variations in their visibility in different images, depending upon image resolution, the angle of the sun when the image was taken and the degree of contrast in the image. The river category is not considered here likewise because it too is a relatively fixed feature (though the presence of old levees and ox bow lakes in the study area betray a dynamism on another temporal scale). Waterbodies are not considered here because their area and perimeters fluctuate depending upon the timing of the image with respect to flood recession, annual flood depth and evaporation rates. Their perimeters are too plastic to be meaningful here.

Table 1. Area of each land use/land cover class, in hectares and organized by year.

	Area (ha)		
LULC Class	1958	1992	2005
Shrubland	513.551	1023.880	1149.937
Grassland	7267.841	4965.160	5342.467
Hillock	31.516	131.850	95.169
Ricefield	3566.363	5313.260	4715.745
River	48.948	55.810	65.316
Settlement	66.385	67.640	116.952
Waterbody	739.864	676.900	750.594

Shrubland cover nearly doubled between 1958 and 1992, jumping from 513.55 ha to 1023.88 ha. This trend of continues into 2005 (1149.94 ha), though the jump is much less pronounced (percent change 10.96%). The increase from 1958 to 1992 is likely due to the withdrawal of agricultural production to areas closer to the village during the instability of the late 1960s and early 1970s, as described by village residents, Evans et al. (2005) and Pel et al. (2002, 2004). This allowed woody species to spread into formerly cultivated areas and grasslands.

From 1958 to 1992, the area of grassland decreased 46.38%, from 7267.84 ha to 4965.16 ha; while from 1992 to 2005, it increased 7% to 5342.47 ha. Much of the decrease in grasslands from 1958 to 1992 appears to be due to village population growth and agricultural expansion.

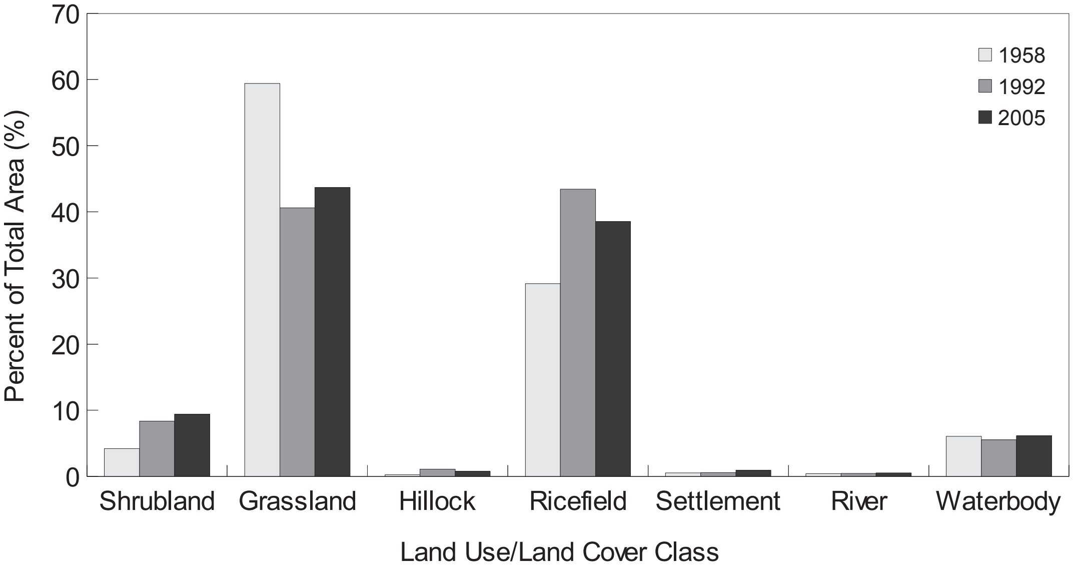

Figure 4. Percent cover for each land use/land cover class, by year.

Over the 34 years from 1958 to 1992, ricefields increased 32.88% from 3566.36 ha to 5313.26 ha. In the following 13 years, ricefields decreased in area 12.67% to 4715.75 ha in 2005. The increase is likely due to population expansion.

Settled areas showed little change from 1958 to 1992, increasing 1.85% from 66.39 ha to 67.64 ha. However from 1992 to 2005, settled areas increased from 67.64 ha to 116.95 ha, a jump of over 42%. This is likely due to two factors: population expansion and the increased security on the floodplain which followed the demilitarization of the Khmer Rouge in the late 1990s. These factors caused both expansion of the borders of Roka Village, as well as the proliferation of smaller settlements on outlying hillocks on the floodplain in areas which had formerly been under the control of Khmer Rouge soldiers or otherwise beyond the reach of the national government.

LULC Change Over Time: LULC Trajectories

While the from-to areal and percent change data are valuable in tracing gross trends over the study area, their spatio-temporal resolution is too coarse to track transition sequences associated with specific areas. For this, an analysis of landscape trajectories may be used.

This landscape trajectory raster contained 249 categories for each combination of the 7 LULC classes that occurred between the maps. These categories ranged in how much area they covered, from 16.75% to less than 0.01% of the study area. Categories comprising a very small proportion of the landscape were not included in this discussion because they may be noise due to small inconsistencies in digitizing features across the image set. The 12 dominant trajectories are presented in Table 2. Of these, several trajectories include the pixels which did not change category at all over the course of the study period. Two trajectories represented areas where forests had expanded into grasslands between 1958 and 1992, and was subsequently cleared, and in one case cultivated (trajectory GFR) and in the other left to return to grassland (trajectory GFG).

While some expansion took place at the riparian forest at the Steung Slap margin, shrubland encroachment further onto the floodplain was limited as local abiotic factors such as soil moisture and flooding keep riparian forest in check (trajectories FFR and FRR, Table 2). Much of the expansion of shrublands took place adjacent the three largest permanent lakes near the southern and eastern edges of the study area, as well

Table 5. Dominant land use/land cover (LULC) change trajectories ("pixel life histories") calculated through the comparison of categorical LULC change maps of the study site from the years 1958, 1992 and 1958. Area is in hectares. Percent Area is the percentage of the total study area.

Category Number	Sequence Code	Description	Area	% Area	Notes
3303	GGG	1958 grassland-1992 grassland-2005 grassland	3575.06	16.75	Consistent across years.
5505	RRR	1958 ricefield-1992 ricefield-2005 ricefield	2433.24	11.4	Consistent across years.
3503	GRG	1958 grassland-1992 ricefield-2005 grassland	1153.82	5.41	Agricultural expansion between 1958 and 1992, subsequently abandoned.
5503	GRR	1958 grassland-1992 ricefield-2005 ricefield	896.53	4.2	New rice field expansion from 1958 to 2005.
5303	GGR	1958 grassland-1992 grassland-2005 ricefield	486.93	2.28	New rice field expansion from 1992 to 2005.
5305	RGR	1958 ricefield-1992 grassland-2005 ricefield	427.97	2.01	Re-expansion of rice production into abandoned farming areas.
8808	WWW	1958 waterbody-1992 waterbody-2005 waterbody	404.61	1.9	Consistent across years.
2503	GRF	1958 grassland-1992 ricefield-2005 shrubland	289.33	1.36	Grassland converted to agriculture between 1958 and 1992, then abandoned allowing spread of shrubland.
2202	FFF	1958 shrubland-1992 shrubland-2005 shrubland	279.42	1.31	Consistent across years.
2203	GFF	1958 grassland-1992 shrubland-2005 shrubland	274	1.28	Shrubland expansion into grasslands between 1958 and 1992.
3305	RGG	1958 ricefield-1992 grassland-2005 grassland	184.55	0.86	Ricefields abandoned since 1958, returned to grassland.
3505	RRG	1958 ricefield-1992 ricefield-2005 grassland	179.25	0.84	Ricefields abandoned since 1992, returned to grassland.

as in the along the sinuous river which runs south of the village, draining into the Steung Slap (Figure 5a).

Grassland expansion took the form of abandoned rice fields, either abandoned since 1958 or since 1992 (trajectories RGG and RRG, respectively, Figure 5b). Rice fields abandoned since 1958 appeared largely along the grassland-rice field frontier. While rice fields abandoned more recently appeared in the southern portion of the study area, between the two largest permanent lakes and the Steung Slap.

Much of the agricultural expansion took place along the rice field-grassland frontier. However, large areas were also opened between 1958 and 1992, deep in the grasslands far from the frontier in the western portion of the study area (landscape trajectories GRR and GGR, Table 2, Figure 5c). Many of these areas were then abandoned between 1992 and 2005 (trajectory GRG, Table 2). Additionally, there was one area where a new rice production system emerged, along the margins of one of the lakes (trajectory WWR, Figure 5d), which will be further discussed in the case study to follow.

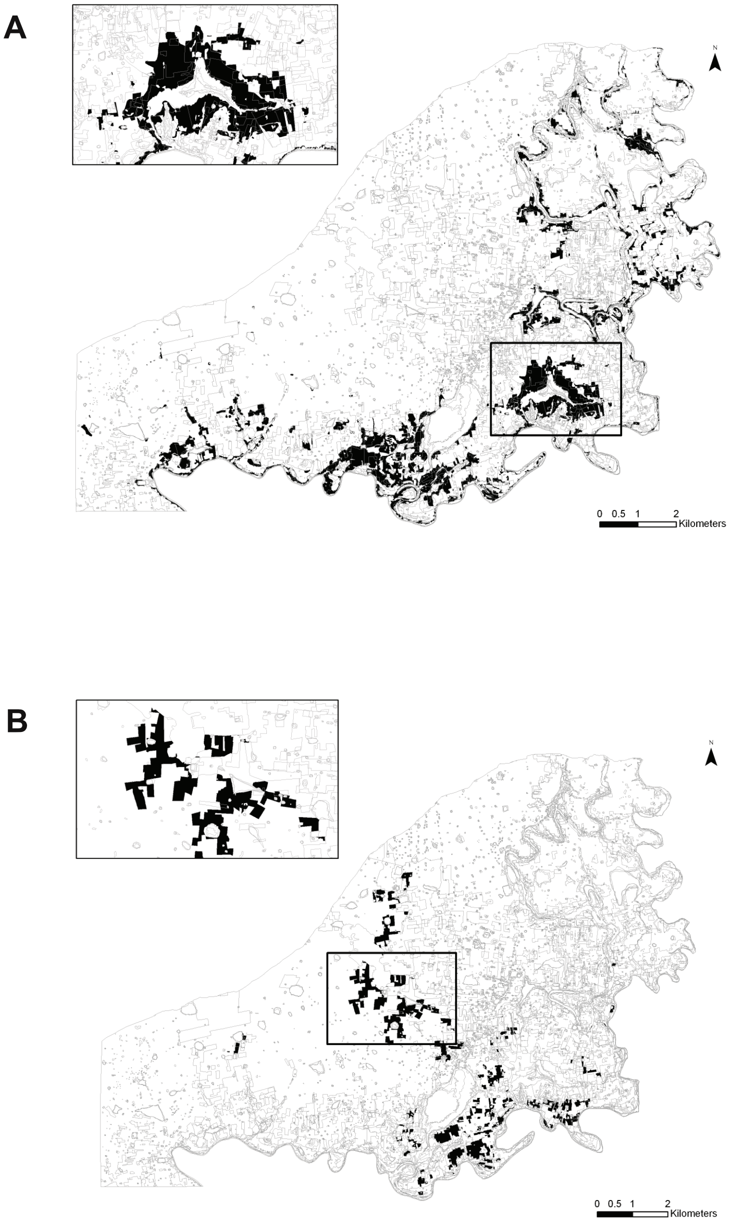

Figure 5. Map of the study area: land use/land cover trajectories. Borders of parcels which correspond to a particular land use/land cover trajectory are outlined in gray (Table 5). A. Parcels which correspond to an expansion in shrubland over the course of the aerial photograph time series are filled in black, inset details Boeng Tuk Sram (the second largest lake in the study area, and the site of much shruband expansion); B. Parcels which correspond to an expansion in grassland over the course of the aerial photograph time series are filled in black, inset details an area of the frontier between savanna and ricefields.

Figure 5 (cont.). Map of the study area: land use/land cover trajectories. Borders of parcels which correspond to a particular land use/land cover trajectory are outlined in gray (Table 5); C. Parcels which correspond to an expansion in ricefields over the course of the aerial photograph time series are filled in black. The inset area shows details around Boeng Tuk Sram, the second largest permanent lake and wetland in the study area; D. Parcels which correspond to the re-emergence of dry season rice production in the late 1990s are filled in black. The inset area shows details from the area where this occured, Boeng Trawsaing.

Landscape Ecological Indices

Landscape ecological indices calculated for LULC categorical maps for each year are presented in Table 3. Contagion is a measure of the interspersion of LULC classes (Li and Reynolds 1993).

Table 3. Landscape ecological indices calculated for land use/land cover categorical maps, by year.

	Index Value		
Index	1958	1992	2005
Contagion	3.084	2.918	2.895
Fractal Dimension (P-E method)	1.122	1.189	1.054
Perimeter-Area Ratio (corrected)	1.679	1.69	1.567
Shannon Diversity Index	1.037	1.198	1.233

Higher values indicate a landscape which is patchy, with more interpenetration of LULC classes. In this case, contagion decreases from 3.084 in 1958 to 2.896 in 2005, suggesting a consolidation of LULC classes, as patches of each class became larger.

Fractal dimension (measured here by the perimeter-area method, Sugihara and May, 1990) is a measure of the irregularity or roughness of the perimeter of each patch of each class. Lower values suggest more regular patch perimeters and have been shown in some studies to suggest increased human management of the landscape (Turner 1990, Mladenoff et al. 1993). In this case, fractal dimension rose from 1.122 in 1958 to

1.189 in 1992, before dropping again to 1.054 in 2005. This suggests that patches became more irregular in shape between 1958 and 1992, which may correspond both to the increase in shrubland cover between those years as well as the uneven expansion of rice fields into the grassland agricultural frontier, which has a ragged appearance in the aerial photography.

Perimeter to area ratio is another measure of patch shape, calculated in meters per Hectare (Baker and Cai 1992). A high value suggests that many patches have long or complicated boundaries, while a low value suggests a simpler shape (Turner et al. 1989, Turner et al. 2003). In this case, perimeter-area ratio changes little. Though the slight increase between 1958 and 1992, and the slight decrease from 1992 to 2005 suggest a pattern similar to that suggested by the fractal dimension values.

Derived from Information Theory, the Shannon diversity index is a measure of both the diversity of LULC classes as well as the distribution of area amongst these classes (Turner 1990; Shannon and Weaver 1962). While the index increased steadily from 1.037 to 1.233 between 1958 and 2005, across all three maps the number of LULC classes remained constant. This suggests an increasing evenness or equitability between the 7 LULC classes. Though this equity is relative. The LULC change areal data (Table 1) show that for all years there is a wide disparity among LULC classes.

In aggregate, these indices suggest that the pattern of the landscape shifted from more complex to less complex over the 47 years included in this study. Patch perimeters became more regular (e.g. the relatively straight lines of rice field borders), while the area covered by each category became more evenly distributed. This trend was not, however, linear. From 1958 to 1992, there are signs of increasing complexity. This was then followed by decreasing complexity by 2005.

Discussion

Broad Patterns I: Agricultural Expansion

As detailed above, the area used for rice production was expanded nearly 67% over the 47 years of the study period (Figure 4). This agricultural expansion may have been due in part to population growth. No early population records for the village are available. However, village elders estimate that there were approximately 400 houses in the village in the 1960s. While according to village records, there were 524 households in 2008. The intervening period remains unclear. Many were certainly lost to illness, malnutrition and political killings under the Khmer Rouge. While according to oral histories, the fall of the Khmer Rouge in 1979 marked an increase of in-migration to the village from surrounding areas.

Recent population data are only available at the commune level (Figure 6), the next administrative level above the village level. They indicate an increasing population over the years 1998 to 2008. As the village is well connected to National Road 6, and is only 10 km from the urbanized provincial seat, it is possible that Roka Village shares these trends.

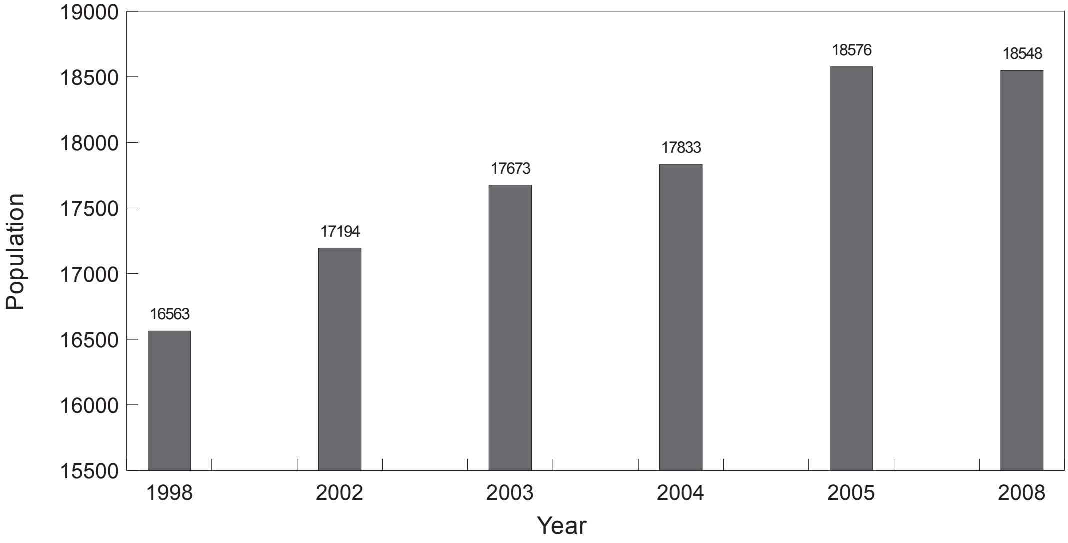

Figure 6. Population of Sangkat Srayov, Kampong Thom Province (National Institute of Statistics, Ministry of Planning).

In addition to demographic trends, local custom may also have been a factor. The norm in Roka Village is to divide family land amongst the children, with allocation of inherited parcels depending upon the quality of the land and in some cases, upon the wealth of the family into which the child marries. It is not uncommon for individual parcels to be split when families do not have enough parcels to present entire fields to each child. This pattern of splitting fields leads to smaller and smaller fields as the generations progress. When these land holdings are too small to produce enough rice to feed the family, in some cases new land is cleared, thereby driving expansion.

These factors, when taken in the context of the 46% increase in the area of settlements revealed in the LULC analysis, as well as the landscape ecological analyses that suggest that the landscape became progressively becoming more human-modified, indicate that population expansion is one *possible* explanation for the expansion of agriculture on the floodplain around Roka Village. Despite the argument being shorn up by the LULC and landscape ecological analyses, the absence of village-level demographic data weakens this point. Officials of the Kampong Thom provincial office of the Ministry of Planning did not have data collected prior to the 1998 census. If such data ever existed, they were likely lost under the Khmer Rouge government along with the myriad other official documents destroyed during that period.

Broad Patterns II: Shrubland Expansion

The landscape trajectory analysis has demonstrated that the vast majority of new rice fields opened between 1958 and 2005 were in grasslands, with cleared shrubland representing only 0.28% of the study area (Table 2). Over the same time frame, shrubland cover expanded by over 55% (Figure 4). Published reports from elsewhere in Kampong Thom Province (Evans et al. 2005, Sokha 2002), as well as the reports of Roka Village residents themselves suggest that this was due to the security situation in the area. From the onset of the civil war, around 1970, through the late 1990s, the floodplain to the south of the village was considered too dangerous to visit. Distant rice fields were abandoned. Collection of firewood and fodder grasses was curtailed. Despite the near continuous presence of soldiers of one faction or another in these areas, as well as fighting between factions, forests were not harvested, and likely grasslands were not burned annually as they had been (and are today). This allowed the emergence and dominance of woody plants in areas which had been grasslands (trajectory GFF, 274 ha, Table 2) and rice fields (trajectory RFF, 39.35 ha).

Case Study

Re-emergence of Small-Scale Dry Season Rice Production: Confluence of Ecology, History and Agency

By examining the trajectories of change for individual pixels, it is possible to rough out the contours of land use histories for specific sites on the floodplain. With detailed on-the-ground interviewing, it is possible to refine and contextualize these histories. The following case study illustrates the multi-scalar complexity which is often glossed in remote sensing studies as “change.” The case study details the emergence of dry season, flood recession rice production in the study site in the late 1990s. It is not an attempt to recast a dominant narrative, as for example Fairhead and Leach's (1996) “*Misreading the African Landscape*.” It is the recounting of a historical moment, as well as an ennumeration of the interactions of event and process, which manifest physically on the landscape.

This transition was first mentioned in interviews conducted in 2007 in the stories recounted by floodplain farmers. Later analysis of LULC trajectories confirmed that sometime between 1992 and 2005, 58 ha of landscape previously classified as a waterbody was converted to rice production (LULC trajectory WWR, Figure 5d). This took place along the margin of a lake, Boeng Trawsaing. Though the shoreline fluctuates with the rise and fall of the annual floods, Boeng Trawsaing is the largest permanent lake in the study area, at approximately 1 km^2. In the present day, as in the 2005 image, the margins of this lake are used for the production of flood recession rice by both village residents and seasonal migrants. Without richer context, the complexity and historical contingency of this transition are not apparent. In fact, the emergence of this production system is a confluence of ecological setting, individual agency and processes of social change accompanying the end of the civil war.

In the 1990s, that area of the floodplain was under the control of Khmer Rouge (KR) soldiers. Through the 1980s, relationships between village residents and the soldiers had been peaceful, if wary. Generally, village residents avoided them and the areas under their control but would occasionally trade with them. Sporadic violence was confined to factional fighting within the KR ranks. However the early 1990s took a more violent turn as KR soldiers began to occasionally kill or kidnap Roka residents. And on at least two occasions, they entered the village and burned homes. This violence was not confined to Roka Village. In 1993, the nearby village of Rolous was rased in order to establish a position from which to shell Kampong Thom. This violence echoed broader tensions in much of the Cambodian countryside, as the remnants of the KR actively engaged in a civil war with nationalist forces. The violence in Roka subsided by 1994 with the arrival of the United Nations Transitional Authority (UNTAC) peacekeeping forces. However, the KR remained on the floodplain and village residents still feared them. In 1998, a handful of Roka residents established a rapport with these soldiers, and were subsequently allowed to fish on Boeng Trawsaing. Not long after, the fishermen expanded their activities to include the cultivation of dry season rice along the lake's margin.

A number of factors contributed to the emergence of this production system. Though under the soldiers' control, the area around Boeng Trawsaing was not legally owned by anyone. It had been protected from development by the presence of the soldiers, and remained out of the reach of the state. Thus this land could be claimed and put to use without the protest of either local officials or other village residents.

As mentioned above, while no statistics are available for village population at that time, it was likely growing. Cambodia saw a “baby boom” in the years following the fall of the Khmer Rouge (crude birth rate 44 births per 1000 people, Dasvarma et al. 2002). Roka was likely sharing in this, increasing pressure on a resource base limited by the threat of violence. But as security returned, likely some looked further afield to access land and other natural resources.

Small-scale dry season rice production was not unknown in Roka prior to 1998. In 1985, the Italian international development organization Caritas administered a program which encouraged dry season rice production along river banks close to the village. They supported this project with training and equipment, including irrigation pumps. They also organized fdry season rice production groups in the village. It is interesting to note that one of the first men to colonize and cultivate the margin of Boeng Trawsaing lived adjacent to the leader of Roka's dry season rice production group.

Seed was also available. In 1990, the (then) Cambodia-IRRI-AusAid Project (CIAP) released several quick-maturing seed varieties, including IR 66, which remains by far the most popular seed variety among flood recession farmers in the present day. At that time, CIAP was also implementing a nationwide extension education program for the production of rapidly maturing rice varieties early in the dry season as a replacement for slow-maturing deep water rice varieties that had been lost in the war.

Thus through this confluence of factors: the geography of the floodplain, the incentive to expand production due to increasing population, the availability of technical expertise, equipment and seed (through connections with international development organizations), and the agency of individuals, flood recession rice emerged around the edges of Boeng Trawsaing. While the presence of this system is readily observable through remote sensing, a holistic understanding of the processes leading up to its appearance would not be possible without the application of additional methodologies.

Conclusion

As this case study illustrates, a holistic understanding of landscape histories and change dynamics demands a hybrid methodology, beyond a from-to LULC change analysis. The use of LULC trajectories allows for individual pixel life histories to be developed, shedding light on particular sequences of change between categories and where these occurred. Incorporating oral histories and other data sources builds a richer explanation of the change, including information from other scales of social organization. Such multi-scalar explanations of change are important As the case study illustrates, landscape dynamics and production system change do not just "happen." They are a product of on-going social and ecological processes operating at multiple scales, from the individual person or individual parcel to the national and international.

Chapter 3

Ten Centimeters Make a Difference: Phytosociology of the Tonle Sap Floodplain, Cambodia

Introduction

Governed by monsoon rain cycles and the annual floodpulse of the Tonle Sap Lake, the floodplain is a landscape of stark contrasts. In the dry season, the landscape is parched. The soil is baked hard and fires are common. The onset of the rainy season brings regrowth. It also brings floodwaters as the Tonle Sap Lake absorbs the overflow from the swelling Mekong River. The lake is also at the center of a watershed which drains the uplands which lie beyond the floodplain. Together these water sources change the terrestrial landscape of the dry season into an aquatic landscape, changing from savanna to lake for several months every year. The dynamics of this annual flood cycle have led to a distinctive flora, adapted to the peculiarities of this system. Though the Tonle Sap and its surrounding floodplains is the largest wetland in peninsular Southeast Asia, its flora and ecological processes are poorly understood and little researched (McDonald et al. 1997). The focus of this study is to address this gap by characterizing plant communities from one site on the floodplain south of the village of Roka in Kampong Thom Province. Building on the land use/land cover (LULC) classification of the floodplain landscape outlined in Chapter 2, the following guiding questions will form the foundation for this analysis:

- Which plant species are found in each land use/land cover type described in Chapter 2?
- Within LULC classes, how are these species structured into communities? What is the composition of these communities, and within these communities how are populations of the more dominant woody species structured?
- What are the factors which govern change in the extent or structure of these communities? In particular what is the effect of past land use history (LULC trajectory, Chapter 2) and present-day land use on floristic composition?
- How well does the LULC classification scheme introduced in Chapter 2 map onto actual floodplain plant communities? How much floristic heterogeneity is masked in the necessary generalization of land use/land cover classification? In terms of floristic composition, how do the LULC categories differ and how are they similar? How much do communities overlap between LULC categories?

Previous Research on the Tonle Sap Floodplain

The flora of Cambodia has not been as well studied as those of neighboring nations. This owes largely to the many years of civil war and social unrest which colored the final decades of the Twentieth Century. With the return of civil stability in the 1990s, research began anew building upon the handful of studies dating from before the war. Notable among them is Rollet's (1972) 3-part overview of the flora of Cambodia in which he discusses major vegetation formations throughout the country. Though he shares inventory data in many cases, such broad geographic reach necessitated generalization in terms of vegetative communities. Pertinent to this study, he lumped together the entire flora of the Tonle Sap floodplain into one category, *“forêt inondée.”* This single category included the flooding forest found at the lake margin, as well as flooding shrublands and savannas further up on the floodplain. In addition to Rollet, other French research was published at that time, including Martel's (1975) ethnobotanical study which focused on communities in Siem Reap Province and the vegetation map produced by Legris and Blasco (1972) which included notes on floristic community composition. Of recent work, more research effort has been focused on the flooding forests at the Tonle Sap Lake's dry season margin, as well as the montane forests of the northeast and southwestern regions of Cambodia. However, a handful of studies addressed the savannas of the floodplain, at least tangentially if not as a central focus.

McDonald et al.'s (1997) botanical survey completed in preparation for the demarcation of the UNESCO Tonle Sap Biosphere Reserve, is among the most comprehensive and widely cited. Their work focused largely on flooding forest along the Tonle Sap margin, with one collection site in the shrublands. More recently, Araki et al. (2007) performed TWINSPAN and DCA analyses on inventory data which they collected from the floodplain in Siem Reap Province. Sampling 67 10 m x 10 m quadrats, they found 7 different vegetative communities. They also highlighted the importance of *Barringtonia acutangula* across all 7 communities and speculated that in the past, it might have been the dominant woody species throughout the floodplain.

Returning to the macro scale of Rollet's pre-war studies, Rundel's chapter in Smith's Cambodian biodiversity report (Smith 2001) discussed the flora of Cambodia, presenting numbers of endemics and affinities with regional flora. Other reports (Rundel 1999, 2009) presented discussions of the flora of peninsular Indochina, including Cambodia and the Tonle Sap floodplain.

Other studies focused on different subjects, but included lists or descriptions of floodplain flora. Lamberts (2001) authored a study of the small-scale gillnet fishery on the Tonle Sap floodplain. Included in the report was a list of plants which were growing at sites where sample nets were set. The Bengal florican (*Houbaropsis bengalensis*), an endangered bustard, was the focus of Davidson's 2005 masters thesis. Floricans spend part of their lifecycle amid the grassy patchwork of the floodplain. Davidson characterized some of these grassland communities where floricans had been found. In a later review, Davidson (2006) presents the literature of the diversity of the flora and fauna found in the Tonle Sap Biosphere Reserve.

Following a more historical approach, Grunewald (1993) treats agriculture and fisheries at the end of the civil war. This includes a discussion of floodplain ecology and the importance of the flood pulse as it relates to plant and fish productivity. He also includes a list of floodplain plant species.

Methodology

Data Collection

Descriptive ecological inventory focused on four of the LULC classes described in Chapter 2: Shrubland, Grassland, Hillock and Ricefield. Transect locations were randomly selected, stratified by LULC class (as categorized using the 2005, 1:25,000 scale orthophoto), using the Hawth's Tools extension for ArcGIS 9.2. Twenty sites each were generated for both Grassland and Ricefield, the dominant land covers. Ten sites each were generated for Shrubland and Hillock. The number of sample sites was disproportionately greater for the Shrubland and Hillock classes. These classes comprise a small fraction of the total landscape, thus more sites were chosen in order that they be adequately sampled. Back-up transect locations were selected at the same time, to ensure that data could still be collected in case some of the initially generated transect sites were not accessible. The total number of transects (60) was based on the maximum number of samples that would be possible to collect in a 2 month field trip. Coordinates (latitude and longitude) for each transect are available in the appendix.

Transects were rectangular, composed of 5 plots laid out end to end and each measuring 20 m long by 10 m wide. Within each plot, two 1 m square sub-plots were systematically placed along the center line at either end of the plot (transect schematic included in the appendix). A rope and stakes were used to mark plot location during data collection. Common names and diameters of all woody plants occurring in the transect and measuring at least 1 cm in diameter were recorded.[7] In each sub-plot, common names and percent cover were recorded for all herbaceous species and woody species below the 1 cm diameter cut-off (including seedlings).

Three local research assistants were hired to assist with inventory data collection and plant identification. All 3 were over 60 years of age, two having lived in the village for over 30 years and one for his entire life. The latter was also known in the area as an expert in medicinal plants.

Each transect was inventoried using the same general procedure. Sites were programed into a handheld GPS (Garmin GPSMAP 360C) and also plotted on a large copy of a 2004 digital orthophoto. The GPS was used to locate the sites in the field[8], while the map was used for route planning. Due to the distances involved, motorcycles were used to travel between the village and inventory sites. Upon arrival at each inventory site, the location was described with respect to local landmarks and nearby topographic features. Vegetation structure was described and other information about the site was recorded, including soil types (per local soil categories), typical flooding depths and land use history, if known to the research assistants.[9]

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[7] For the most part, diameters were measured basally. Most of the woody species found on the floodplain were shrubs, with relatively low canopies and basal branching. Diameters of trees were measured at breast height, 1.4 m. Whether diameter was recorded basally or at breast height was noted during data collection. However, these data were pooled for analysis due to the relative rarity of diameters measured at breast height.

[8] According to the GPS unit's display, spatial error frequently ranged from 8-11 m even on flat, open landscapes. While not a great distance, it does complicate re-visits to the exact point where a transect was set to track vegetation change over time.

[9] It was not possible to systematically collect these ancillary data because the research assistants were not familiar with all of the sites inventoried.

Data Analysis

Common Names and Plant Identification

As many common names as possible were linked with scientific names using published lists of Khmer language common names (Phon 2000, Kham 2004, McDonald et al. 1997, Quattrocchi 2006, Canton et al. 2010, Lewitz and Rollet 1973, Grunewald 1993, Martin and Chanthy 1997, Martel et al. 1969, Headley 1997, Headley 1977). Many of the woody plants, particularly the most common species, were found in these sources. Identification of herbaceous plants proved more difficult. In some cases, folk generic names were listed in published sources while folk specific names used at the study site could not be located. Many common names simply could not be found, likely owing as much to regional diversity in common names as to the lack of systematic study of Khmer ethnoecology Where possible, taxa lacking scientific names were identified to family.

Characterizing Sample Effort and Inter-plot Variation

To verify adequate sample effort, running means of basal area and the number of species observed per plot were plotted. For this calculation, total basal area and number of species per plot were calculated. These values were set into a random sequence and used to calculate running means. These means were plotted against number of plots sampled. For both total basal area per plot and number of species per plot, variability in running means dampened as the number of plots approached their maxima, suggesting further sampling effort would yield marginal returns. However, the curves are occasionally punctuated by outliers, indicating individual plots which contained an unusually high or low basal area or number of species, contrary to the trend of others in the class. This points to the patchiness of the environment and the heterogeneity within LULC classes, and in contrast to the leveling curves suggests that further sampling might reveal additional information about rare species or clusters of species.

Species Richness and Shared Species

In lieu of diversity statistics, species richness, as the average number of species observed per plot as well as the total number of observed species per LULC class, is presented as a measure of alpha diversity (McCune et al. 2002). As a measure of beta diversity, the number of species shared between classes was calculated using EstimateS species richness estimating software version 8.2.0 (Colwell 2009).

Importance Values

As a method of digesting frequency, abundance and basal area data into an aggregate score for each species, importance values were calculated for each species in each LULC class (Brown and Curtis 1952). Aggregated values which pooled specific data across LULC classes were also calculated. The calculation procedure for the woody plants and the herbaceous plants was similar, though slightly different. For the woody species, individual observations of abundance, frequency and basal area were relativized (presented as decimal forms of their percentage of the total) and summed for each species. The average of these three values was then multiplied by 100 to generate an importance value ranging from 1 to 100. For herbaceous species, a similar value was generated using relativized forms of total percent cover and frequency (Dalrymple et al 2003).

Importance value presents a relatively simple method of calculating the interplay of dominance and prevalence. The use of importance value can be problematic because it is not possible to back-calculate to determine the contributions of basal area, frequency or abundance (McCune et al. 2002). However, to circumvent this weakness, relativized values for basal area, frequency and abundance for each species in each LULC class are presented in the appendix.

To visualize assemblages of species within each LULC class, a modified relevé table was prepared using data for all 194 species, both herbaceous and woody (Mueller-Dombois and Ellenberg 1974). Relevé tables are usually prepared using abundance/dominance or percent cover scores calculated from data collected using Braun-Blanquet's particular relevé methodology. This data collection methodology was not used in this study, so relevé tables were prepared using a slightly different method. A matrix of importance values was grouped by species and LULC class. LULC classes were ranked according to the proportion of their flora which was found in more than one LULC class. The class with the highest proportion of woody species found in all 4 LULC classes was ranked first. Within this framework, species were ranked by importance values from greatest to least. This approach yielded a table similar to the classic relevé table which serves the same purpose: a visual display of groups of co-occurring species along with some measure of commonness or ecological importance.

Dominance-Diversity Curves

Dominance-diversity curves, also known as Whittaker Curves (Whittaker 1965, 1972; Whittaker and Woodwell 1969), were generated from the data sets for importance value from both the herbaceous and woody plants, combined. Similar to rank-abundance curves, dominance-diversity curves are graphs of importance value versus taxon importance value rank.

Being the sum of two relativized data sets, when the woody and herbaceous species data were brought together the complete set of importance values for each LULC class summed to 200. In order for the importance values to sum to 100, each LULC importance value total was divided by 2. Though this changed absolute values, relationships between values and thus between taxa were maintained which allowed generation and comparison of the curves.

Size Class Frequencies

For woody plants, size class frequency graphs can be used to draw conclusions about regeneration, harvest, mortality and other factors which might be affecting stand health. To this end, size class frequency charts were prepared using the entire woody data set, broken down by LULC class to highlight any differences or similarities between them. To prepare these graphs, inventory data were expanded to yield frequencies per hectare. These were binned into size classes in increments of 1 cm and then plotted.

While these curves present an overall picture of stand development, they are aggregate data sets and so may mask dynamics occurring in populations of particular species. As a partial remedy to this problem, size class frequency graphs for two individual species were prepared: *Gmelina asiatica* L. (Lamiaceae) and *Barringtonia acutangula* (L.) Gaetrn. (Lecythidaceae). These species were chosen because *Gmelina* ranked highest in importance value across all four LULC classes, by far. *Barringtonia*, while frequently highly ranked in importance value, was also frequently mentioned as an important species by village informants and has been identified as an ecologically important species in previous studies (Araki et al. 2007, Rundel 2009).

Results

Transect Profiles

Figures 7a-d are representative transect profiles and images from each land use/land cover class. Images were taken at the start of each transect, and sighted along the center-line of the transect. These profiles show how niches are partitioned through the relationships among species with respect to elevational gradients.

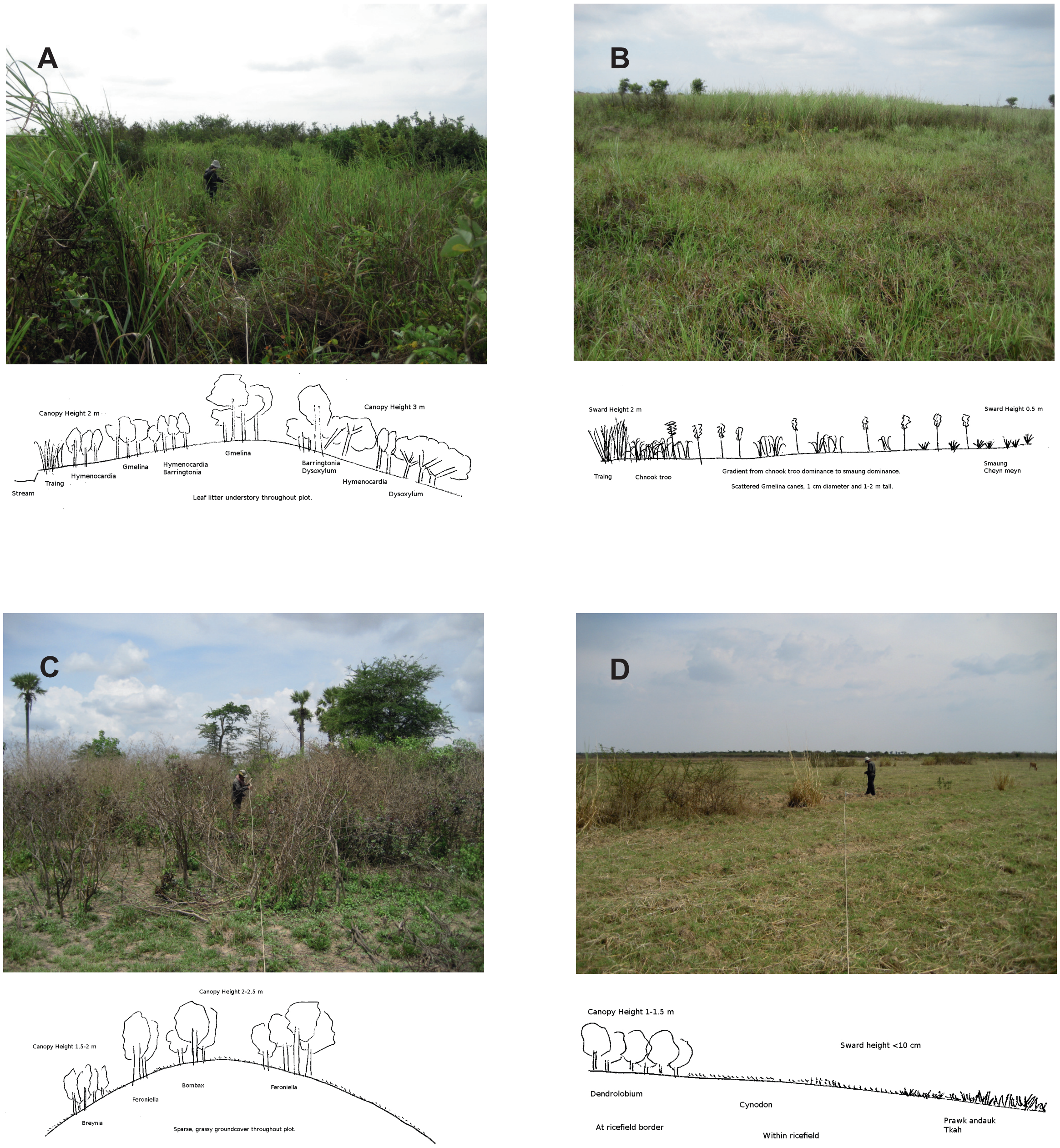

Figure 7. Representative images of land use/land cover classes. Each image was taken at the beginning of a transect, and is accompanied by a transect profile which corresponds to that particular transect. Transect profiles illustrate niche partitioning as species are distributed according to edaphic conditions along often subtle elevational gradients. A. Shrubland (transect F7, 04 March 2009); B. Grassland (transect G13, 03 March 2009); C. Hillock (transect H8, 21 March 2009); Ricefield (transect R17, 22 February 2009).

Importance Values

A complete list of recorded taxa and their importance values (along with relative basal areas/percent covers, abundance and frequencies used in the calculation of importance values) is presented in the appendix. Below are the 10 highest ranking taxa by importance value for each LULC class, as well as the entire site. Woody and herbaceous species are presented separately (Table 4).

Of immediate note is the difference in partitioning of importance values. Among the woody plants in most LULC classes, importance value is concentrated in one species (*Gmelina asiatica*) with a steep drop in importance value down to the second ranked species in the list.

In the Ricefield class, *Stephegyne parviflora* ranks a close second in importance behind *Gmelina*. In the Hillock class, the top three species are close in importance value: *Gmelina asiatica*, *Barringtonia acutangula* and *Jatropha curcas*. Among herbaceous species, importance is markedly less concentrated than among the woody species. Overall, the importance value maxima are lower than for woody plants and more taxa share the highest ranks.

Table 4. Species Ranked by Importance Value, Top Ten. Importance values (IV) are presented for the top ten ranking species in each land use/land cover (LULC) class, including values for all four LULC classes in aggregate. Values for herbs and for shrubs/trees are presented separately. Importance values for all species in any one LULC class sum to 100. Common names are italicized and in lower case.

LULC Class	Herbs	IV	Shrubs and Trees	IV
<u>Aggregated</u>	Cynodon dactylon	6.93	Gmelina asiatica	32.51
	Cynodon sp.	5.62	Croton sp.	8.59
	prawk andauk (Poaceae)	4.78	Barringtonia acutangula	8.58
	somoung (Poaceae)	4.64	Hymenocardia wallichii	6.64
	sluk russei (Poaceae)	4.32	Stephegyne parvifolia	5.04
	chnook troo (Poaceae)	4.24	Dysoxylum procerum	3.25
	tkah (Poaceae)	3.26	Peltophorum	3.04
	smaung (Poaceae)	3.15	Zizyphus mauritiana	2.8
	Eleusine indica	3.04	*tlaum andauk*	2.5
	sbauv andah (Poaceae)	2.59	Feroniella lucida	2.29
<u>Shrubland</u>	*smaung* (Poaceae)	14.75	Gmelina asiatica	51.47
	voah preng	10.88	Barringtonia acutangula	11.51
	sluk russei (Poaceae)	8.91	Croton sp.	10.78
	kok cheyn meyn (Cyperaceae)	6.71	Hymenocardia wallichii	5.04
	voah dong preah	6.2	*tlaum andauk*	4.75
	Polygonum tomentosum	5.43	Vitex holoadenon	3.42
	prawk andauk (Poaceae)	4.74	Dysoxylum procerum	2.72
	sbauv aich moan (Poaceae)	4.27	Dendrolobium sp.	1.77
	traing (Poaceae)	4.21	Antidesma ghaesembilla	1.41
	chnook troo (Poaceae)	3.89	Cratoxylum cochinchinense	1.31
<u>Grassland</u>	*somoung* (Poaceae)	9.9	Gmelina asiatica	38.06
	chnook troo (Poaceae)	8.91	Barringtonia acutangula	15.86
	prawk andauk (Poaceae)	8.36	Hymenocardia wallichii	12
	sluk russei (Poaceae)	5.52	Croton sp.	8.53
	Cynodon dactylon	4.38	Dysoxylum procerum	4.35

	smaung (Poaceae)	4.37	Stephegyne parvifolia	4.13
	Echinochloa crus-galli	3.68	*tlaum andauk*	2.63
	kok cheyn meyn (Cyperaceae)	3.43	Sesbania javanica	2.52
	Coldenia procumbens	3.35	*bai krium*	2.5
	jeung tien	3.08	Antidesma ghaesembilla	1.44
<u>Hillock</u>	Cynodon dactylon	12.73	Gmelina asiatica	10.41
	Cynodon sp.	9.23	Croton sp.	8.91
	Cyperus rotundus	8.43	Jatropha curcas	8.86
	Eleusine indica	8.08	Peltophorum sp.	6.91
	sbauv andah (Poaceae)	6.45	Zizyphus mauritiana	6.69
	Chrysopogon aciculatus	3.57	Chromolaena odorata	5.89
	andaht buah	2.59	Feroniella lucida	5.37
	sluk russei (Poaceae)	2.43	Barringtonia acutangula	4.86
	Coldenia procumbens	2.06	Hymenocardia wallichii	4.64
	pkah nmahl	1.82	Stephegyne parvifolia	3.59
<u>Ricefield</u>	Cynodon sp.	4.27	Gmelina asiatica	32.63
	tkah (Poaceae)	3.74	Stephegyne parvifolia	28.91
	Cynodon dactylon	2.79	Eriobotrya bengalensis	8.72
	smaung (Poaceae)	2.56	Borassus flabellifer	6.35
	prawk andauk (Poaceae)	2.41	Aeschynomene aspera	4.15
	sluk russei (Poaceae)	2.34	Sesbania javanica	3.95
	Merremia hederacea	2.09	Croton sp.	3.23
	Eleusine indica	1.82	Antidesma ghaesembilla	3.15
	andaht buah	1.73	*trawh*	3
	kok cheyn meyn (Cyperaceae)	1.52	Zizyphus mauritiana	2.09

Species Richness and Shared Species

In terms of observed species numbers, the Hillock class yielded the greatest numbers of both woody and herbaceous species, with 45 and 82 species respectively (Table 5). The fewest woody species were found in the Ricefield class (13 species) while Shrubland contained the fewest herbaceous species (30 species) and a number of woody species similar to Grassland (23 and 24 species, respectively).

Table 5. Species Richness and Species Richness per Plot. Presented are total observed species richness and mean species richness per 10 m x 20 m sample plot for each land use/land cover (LULC) class, including data for all 4 classes in aggregate. Herbs and shrubs/trees are presented separately.

	Herbs		Shrubs and Trees	
LULC Class	Species Richness	Mean Species Richness/Plot	Species Richness	Mean Species Richness/Plot
Aggregated	133	3.54	60	3.32
Shrubland	30	2.54	23	3.04
Grassland	64	3.44	24	3.35
Hillock	82	4.14	45	4.79
Ricefield	74	3.56	13	1.65

Tables 6 and 7 present the number of shared species among the LULC classes, for herbs and woody plants respectively. Shared species were determined by pairwise comparison of LULC class species occurance data as a measure of similarity.

Table 6. Shared Species, Herbs. The results of a pairwise comparison of land use/land cover (LULC) class species occurance data are presented. For each pair of LULC classes, the number of species shared between them is shown. This is a measure of similarity, with LULC class pairs which share a greater number of species being more similar to each other.

LULC Class	Shrubland	Grassland	Hillock	Ricefield
Shrubland	-	26	21	21
Grassland	26	-	35	41
Hillock	21	35	-	42
Ricefield	21	41	42	-

Table 7. Shared Species, Shrubs and Trees. The results of a pairwise comparison of land use/land cover (LULC) class species occurance data are presented. For each pair of LULC classes, the number of species shared between them is shown. This is a measure of similarity, with LULC class pairs which share a greater number of species being more similar to each other.

LULC Class	Shrubland	Grassland	Hillock	Ricefield
Shrubland	-	14	13	10
Grassland	14	-	17	9
Hillock	13	17	-	10
Ricefield	10	9	10	-

Table 8 presents the distribution of woody plant importance value across classes (total importance value per LULC class = 100) based upon the number of LULC classes in which each species is present. For example, 6.15% of the total importance value of woody plants found in the Shrubland class is made up of species found only in one LULC class. While, 81.1% of the importance value is comprised of species found in all 4 classes. Therefore most species found in the Shrublands LULC class are widespread with respect to their distribution across LULC classes. Interestingly, 40.21% of the importance value for the Hillock class is allocated to species which were not recorded in any other classes. In contrast, none of the plants recorded in the Ricefield class were unique to that LULC. Among the four LULC classes, Hillock included, species which were found in 4 LULC classes made up the bulk of importance values, ranging from 82.53% of the total importance value for Grassland to 34.82% of total importance value for the Hillock class (Table 8).

Dominance-Diversity Curves

Dominance-Diversity, or Whittaker, curves were used to visualize community structure by taking advantage of both the abundance data of the woody species and the percent cover data of the herbaceous species (Figure 8) (Whittaker 1965). By graphing importance values, both functional groups can be presented as one set. The shapes of these curves are similar to rank-abundance and rank-percent cover curves (calculated but not presented here); however, they summarize more information than either because importance value is based on three parameters rather than a single parameter.

While the curves are similar, the curve for the Hillock class more closely approximates a linear function in contrast to the negative exponential distribution shown by the other LULC classes (Figure 8). This is due to the breadth of environments captured within the Hillock LULC class which are dominated by a more diverse range of species than other classes.

Table 8. Land Use/Land Cover Class Specificity. Table 8 presents the percentage of importance values for shrub/tree species in each land use/land cover (LULC) class which comprise 1 of 4 classes based on the number of land use/land cover classes in which they appear, ranging from 1 (appearing in a single LULC class) to 4 (appearing in all 4 LULC classes). This is a measure of the degree to which it is possible to separate the LULC classes based on their floristic composition. LULC classes with a greater proportion of importance value corresponding to species found in fewer other LULC classes therefore have a more characteristic flora.

	Specificity Class			
LULC Class	4	3	2	1
Shrubland	81.1	11.59	1.88	6.15
Grassland	82.53	10.14	4.72	2.62
Hillock	34.82	5.78	19.44	40.21
Ricefield	71.36	11.88	19.79	0

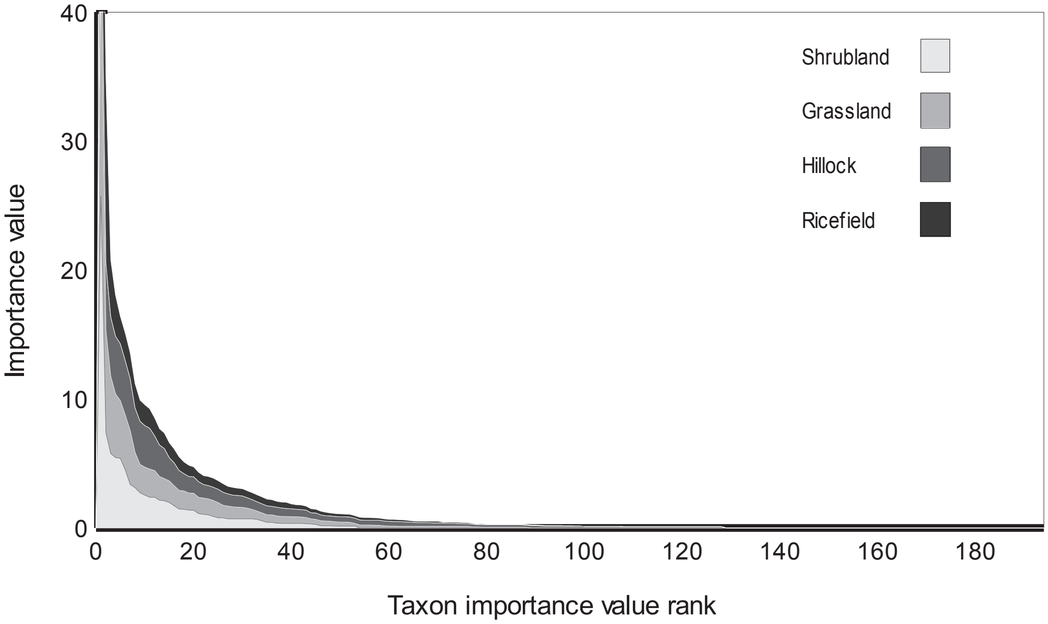

Figure 8. Dominance-Diversity Curves. Species importance values are plotted versus taxon importance value rank, with separate curves for each land use/land cover (LULC) class. By comparing the shape and slope of the curves, it is possible to draw conclusions about community structure.

Relevé Table

Using importance values for all 194 species, both herbaceous and woody, a relevé-style table was prepared. The complete table is presented in the appendix. By presenting a species list sorted by both LULC class and importance value, this table allows the visual analysis of species assemblages. It can also be used to separate species which are widespread in terms of LULC class from species which have a more restricted distribution.

Species Found in a Single LULC Class

Of particular interest are species found only in one class (Table 9). Many of these species represent the long, right-hand tail of the dominance-diversity curves (Figure 8), with relatively low importance values. Seven species were found only in the Shrubland class. Eighteen species were found only in the Grassland class. In the Ricefield class, 19 species were not found elsewhere. The greatest number of species unique to their LULC class were found in the Hillock class, with 59 species. Of these, a number are species associated with settlements and managed areas, including *Jatropha curcas*, *Albizia saman* and *Ceiba pentandra*.

Table 9. Species Observed in a Single Land Use/Land Cover Class. Species which were recorded in only one land use/land cover (LULC) class are listed by LULC class in which they were recorded, sorted by their importance values. Many of these species represent data points in the long, right-hand tail of the dominance-diversity curves (Fig.8).

LULC Class	Name	Importance Value
Shrubland	Vitex holoadendron	1.71
	Cratoxylum cochinchinense	0.66
	nyeeah	0.15
	Acacia thailandica	0.14
	kompleang	0.14
	kawtooul	0.14
	Croton sp.	0.13
Hillock	Jatropha curcas	4.43
	Chromlena odorata	3.17
	Feroniella lucida	2.69
	kontrowie	1.78
	Albizia saman	1.55
	Ceiba pentandra	1.28
	Pithecellobium dulce	0.95
	Zizyphus oenoplia	0.91
	Bombax ceiba	0.88
	Tephrosia purpurea	0.76
	kandaol bat	0.7
	Portulaca oleracea	0.67
	Crateva adansonii	0.62
	Cayratia carnosa	0.61
Ricefield	Desmodium triflorum	0.19
	Gomphrena globosa	0.16
	Limnophila chinensis	0.16
	srawngai kdeaung	0.16
	voah sluk bei	0.12
	bok moat trei andaing	0.08
	kombauwie krawbei	0.08
	pkah kawchan	0.08
	sawsuht	0.08
	trawkay lok	0.08
	cheem	0.04
	daum aich cherook	0.04
	dombei damrei	0.04
	jiet krayn	0.04
	kombao momeeh	0.04
	krawchap chap	0.04
	priel	0.04
	sluk rholooung	0.04
	smau kawntooie krachok	0.04
Grassland	*lpeak tuk*	0.58
	chomtooal bong moan	0.54

kontreang bai saw	0.48
Cyperus rotundus	0.46
smau daik	0.41
Carica papaya	0.4
Streblus asper	0.4
Breynia sp.	0.39
kadeuung bai saw	0.38
Portulaca quadrifolia	0.38
praklop	0.38
Capparis sp.	0.35
Amaranthus viridis	0.31
sandaich duk	0.29
nokieah dei	0.26
kawntrooie	0.21
Achyranthes aspera	0.19
chinchien sai	0.19
Phyllanthus urinaria	0.19
chkrayn	0.18
chinchien momeeh	0.17
Solanum sp.	0.16
Solanum torvum	0.15
banlah dei suhut	0.13
daum bat leuh	0.13
kbuht	0.13
Tamarindus indica	0.12
Annona sp.	0.12
ptee palah	0.12
swai kteeh	0.11
mreah preu	0.11
voah preng (liana)	0.11
Amaranthus spinosus	0.1
ampul prawk playee	0.1
Argyreia obtecta	0.1
chplang awnlooung	0.1
Holarrhena pubescens	0.1
kwien kvahn	0.1
Lagenaria siceraria	0.1

Terminalia cambodiana	0.53
smaung sawkowch	0.4
dombowie chkai	0.22
chleuy	0.12
chuung buah	0.11
sarai	0.1
nyo chmol	0.1
smau aich moan	0.08
kok cherung	0.06
kreung tee	0.05
Lygodium flexuosum	0.05
njohk tuk	0.05
sbai tuk	0.05
Utricularia	0.05
voah andaht trawkoouht	0.05
voah tadaht	0.05

momeeng kmoung	0.1
momun	0.1
smau momeeh	0.1
tawmbok	0.1
trawsout loyn	0.1
trop kmauich	0.1
trup bai	0.1
voah lep	0.1

Diameter Size-Class Frequencies

Diameter Size-Class Frequencies: All Woody Species

The diameter size class frequency curves for aggregated woody species show that recruitment is uneven across years (Figure 9a). This is evident in the irregularity of the smaller size classes. While it is tempting to attribute this to local events such as burning, the widespread nature of these gaps occurring in a range of LULC classes suggests events broader in scope. Such gaps in recruitment may be due to periodic high flooding or unusually long periods of submergence associated with an early onset or late subsidence of the annual flood. However without finer grained data regarding stand age and growth rates, it is difficult to link patterns in diameter size class frequencies with other sources of data such as oral histories of major flood events.[10]

The wider gaps in the larger diameter classes are due to harvest, habit and stand age. The demand for firewood is high, so trees and shrubs are frequently harvested in their entirety or are coppiced. This is most evident in areas closer to settlements and roads. Moreover, many of the woody plants on the floodplain are shrubby in habit with low canopies, basal branching and relatively small diameters. Many of those which escape harvest do not grow to be particularly large anyway. Lastly, these data summarize

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[10] For example, the year 2000 has consistently been mentioned by village residents as being a year with particularly high floods, which adversely affected rice farming. By the same token, many reported that firewood harvest and other floodplain natural resource-based activities were curtailed that year due to the difficulty in accessing resource patches. This reduction in harvest effort could possibly have resulted in an increase in the number of trees recruiting into the next larger diameter size class. However, the effects of an extended period of submergence on *Barringtonia* growth rates are not known. Growth might also have been slowed, negating the effects of the break in harvesting.

diameter size classes across the entire sample which include stands of various ages. Younger stands are dominated by smaller diameter stems with no larger stems.

***Diameter Size Class Frequencies:* Gmelina asiatica**

The diameter size class frequency tables for *Gmelina asiatica* show some of the same characteristics of the size class frequencies of the aggregated woody species (Figure 9b). These include irregularities in recruitment most obvious in the size class distribution data from the Shrubland class. Perhaps more striking is the dramatic diameter cut-off at 6 and 7 cm diameter in the Grassland and Hillock classes, respectively and the 4 cm cut-off in the Ricefield class. Comparing these tables with those of other LULC classes reveals that *Gmelina asiatica* can grow to as large as 20 cm in diameter. However in the Grassland, Hillock and Ricefield classes, it seldom reaches that size. This is due to two factors: harvest, and stand age.

Much of the area of the Grassland and Ricefield classes is burned every year. Hillock areas burn much less frequently, less so than even some areas classified as Shrubland. Burning is therefore not the likely reason for this dramatically reduced size class distribution. All three of these LULC classes are widely used by farmers for farming, grazing and other activities including the harvest of firewood. This suggests that the patterns evident here are due in part to firewood harvest.

This pattern is also indicative of young stands which lack larger diameter stems. The 4-cm maximum size for the Ricefield class is an example of this effect. The Ricefield class included not only ricefields in cultivation (which may have *Gmelina* on field borders) as well as recently abandoned fields which have been colonized by *Gmelina*. The former are kept clear by cultivation activities, while the latter in time may develop into a wooded savanna.

***Diameter Size Class Frequencies:* Barringtonia acutangula**

Diameter size class frequency data are displayed here for all LULC classes except for the Ricefield class (Figure 9c). Over the course of this inventory, only one *Barringtonia acutangula* stem over 1 cm in diameter was found in an area classed as Ricefield.

Like *Gmelina* above, few stems were found which were larger than 16 or 17 cm in diameter. Among stems of smaller diameter, an irregular distribution is seen in all LULC classes. It is possible that this could be due to flood events, as some patterns such as the lower frequencies in the 9 and 14 cm diameter classes are evident across all LULC classes. Despite these irregularities, seedlings (size class 0) remain relatively plentiful (with densities estimated at 100,000 per ha for the total study area).

Larger, irregularly distributed gaps in the larger diameter classes suggest high levels of harvesting, though a mix of harvested and young stands could also produce such a pattern. The importance of harvest in shaping *Barringtonia* populations is also supported by informants who frequently mention *Barringtonia* when discussing clearing of woodland around waterbodies for rice production.

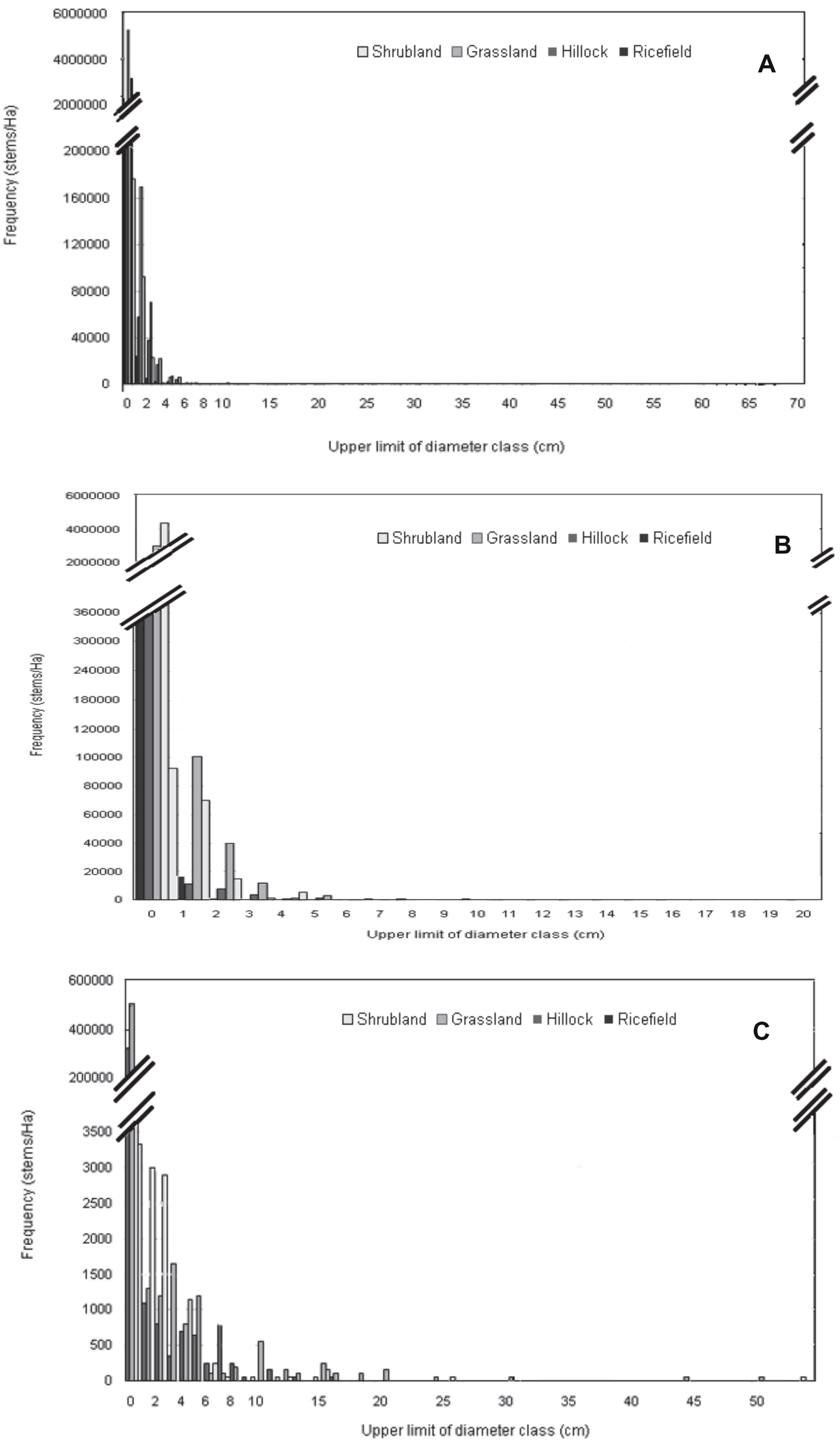

Figure 9. Diameter Size-Class Frequencies by Land Use/Land Cover Class. Data include seedlings (size class 0). Axes are broken in order to display seedling data. A. All woody species inventoried; B. *Gmelina asiatica* C. B*arringtonia acutangula.*

Discussion

Description of the Flora of Each LULC Class

What follows are descriptions of each LULC class based on inventory data.

Shrubland

The Shrubland class comprises several different communities which are dominated by woody plants. These include dense, riparian forests which line the river which forms the boundaries of the study site, sparse wooded savannas deeper in the floodplain as well as woodlands associated with seasonal and permanent wetlands. Most common in this study area are wooded savannas dominated by *Gmelina asiatica* with a 2-4 m canopy, a grassy understory and no middle strata or lianas. The density of these stands is relatively sparse, and they are frequently broken by patches of open grassland.

Sites near depressions with poorly drained soil or close to permanent water bodies feature a more diverse suite of species with a higher canopy (to 5-6 m), including: *Barringtonia acutangula*, *Croton* sp., *Hymenocardia wallichii*, *Vitex holoadenon, Dysoxylum procerum* and others. The most dominant families are Euphorbiaceae and Leguminosae. Notably absent are palms, which are represented by two species of *Calamus* uncommon enough to have escaped sampling in this inventory (McDonald et al. 1997).

As seen throughout the study area in various plant communities, niche partitioning is evident where there is a gradient of soil moisture (see transect profiles, Figures 7a-d). Each species often forms distinct concentric rings around depressions or bands along linear water features, as the soil grades from drier to wetter. One common sequence is: *Gmelina asiatica* to *Croton* sp. to *Hymenocardia wallichii* and *Bridelia* sp. to *Dysoxylum procerum* to *Aeschynomene aspera* and *Sesbania javanica* with *Polygonum tomentosum* groundcover at the lowest and wettest portion of the site.

Riparian forests share some species with other floodplain woodlands. However they lack a grassy understory, having instead a litter-covered floor. Vertical stratification is more complex, including smaller trees and lianas. Some lianaceous species seen elsewhere on the floodplain only as seedlings, grow far into the canopy in riverine forests (such as the inconclusively identified *voah preng*). In addition to those already mentioned, woody species may also include *Antidesma ghaesembilla*, *Vitex holaodenon*, *Cratoxylum cochinchinense* and *Combretum trifoliatum*.

Grassland

The Grassland LULC class is dominated by grasses and sedges, with scattered individual trees and pockets of woodland (smaller than 10 m x 10 m) usually associated with depressions and seasonal wetlands. The most common woody species in drier areas is the widespread *Gmelina asiatica*. Scattered *Stephegyne parvifolia* are found in some areas as well. Depressions and wetter areas share many of the species described in the Shrubland LULC class, including *Barringtonia acutangula*, *Croton* sp., *Hymenocardia wallichii, Dysoxylum procerum, Aeschynomene aspera* and *Sesbania* *javanica.* The landscape is however dominated by a number of grasses, some tussock-forming, others not. Some swards are monospecific (such as by the unidentified grass *chnook troo* associated with *Stephegyne parvifolia*) while others feature multi-layered mixtures of herbaceous species (such as those dominated by species of *Cynodon*). Some unwooded depressions are dominated by sedges and rushes, rather than grasses. Sward height is most strongly affected by the level of grazing. Many sites are grazed to within a few centimeters of the soil surface by domesticated livestock. In unburned, ungrazed areas, some grasses can reach a meter or more in height. Stands of *Saccharum* sp. (*traing*) near one of the large permanent lakes in the study area reach 2-3 m in height.

Hillock

The Hillock LULC class contained the most diverse flora. This is in part due to topography and niche partitioning, as hillocks are among the most dramatic relief on the floodplain. This relief results in a gradient of soil moisture levels and duration of submergence, with the tops of the largest hillocks remaining dry year-round. This floristic diversity is also an artifact of the classification process which lumped several kinds of hillock into one LULC class. These hillocks included riverside levees with riparian vegetation, hillocks close to settlements which featured more evidence of management of both plant community structure and species composition, as well as hillocks farther from the river or settlements with their own distinctive flora.

High riverside levees have a flora similar to the riparian woodland of the Shrubland

LULC class. Lower levees along the two smaller rivers which bisect the study site share more species in common with depression woodlands (low canopied stands of *Gmelina asiatica*, *Barringtonia acutangula*, *Croton* sp., *Hymenocardia wallichii, Bridelia* sp. and *tlaum andauk*).

Hillocks which are near settled areas, or are in some cases settled themselves, have a distinctive plant community structure. Often the grassy groundcover is grazed short, and layers between the understory and canopy are absent. Species present may include trees valued for their products, such as *Borassus flabellifer*, planted both atop hillocks and around their borders; scattered individuals of *Pithecellobium dulce*, *Tamarindus indica* or *Zizyphus mauritiana* alongside horticultural species such as *Carica papaya*.

Other hillocks, in areas commonly used for grazing, are dominated by a single large tree used for shade by the *graziers*. These trees include *Ficus religiosa*, *Albizia saman*, *Sterculia foetida* and *Pithecellobium dulce.*

Hillocks which fall outside of these two categories also have a distinctive flora. One tree species in particular, *Feroniella lucida*, tops the highest hillocks in small clusters of stems to 3-5 m in height. Also found atop these hillocks are *Gmelina asiatica*, *Streblus asper*, *Zizyphus oenoplia*, *Bombax ceiba*, *Chromolaena odorata, Breynia* sp. and *Capparis* sp. Along the edges of hillocks, species more tolerant of flooding may be found, including *Bridelia* sp., *Hymenocardia wallichii* and *Croton* sp. Rarely, *Barringtonia acutangula* is found at these sites, along with other species more common in wetter environments such as *Dysoxylum procerum*. At some sites, thickets of shrubs form around a central individual tree or small stand at the top of the hillock. These thickets can include *Solanum* spp. and *Tephrosia purpurea*, as well as shorter individuals of species previously mentioned such as *Zizyphus oenoplia* and *Chromolaena odorata.*[11]

Many different grasses and forbs are found at hillock sites, though only a handful of grasses are most common: *Cynodon* spp., *Eleusine indica* and *Chrysopogon aciculatus*.

For a more detailed discussion of hillocks and land use, see Chapter 5.

Ricefield

The Ricefield LULC class is dominated by the herbaceous vegetation of the spontaneous pastures which form on rice production sites with the recession of the annual floods. This LULC class also included recently abandoned and recently cleared rice fields. Due to the timing of the images (dry season, 2005), these were impossible to distinguish from recently cultivated rice fields.

The two most common woody species by far are *Gmelina asiatica* and *Stephegyne parvifolia*. These form small stands to 1.5-3 m height in the grassy matrix between rice

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[11] *Jatropha curcas* is found in similar hillock thickets, and might appear to be a common species as it ranked the third highest in importance value among species found in the Hillock LULC class. Despite a relatively high importance value, it is not a widespread species. Rather, it is locally common occuring at high densities at 2 out of the 10 hillock inventory sites.

fields or on slightly higher points of the topography. Individuals and small thickets may be scattered in the fields themselves. *Gmelina* seedlings and small canes are common in fields which were cleared in the last year or had been recently abandoned. *Stephegyne* is also found as clumped individuals within rice fields, where informants report that it is difficult to remove due to persistent sprouting from rhizomes. *Gmelina* is much more widespread than *Stephegyne*, but generally individual stems are much smaller in diameter (resulting in similar importance values from the inventory data). Other species which occur between rice fields, and occasionally within them, including *Eriobotrya bengalensis* and *Zizyphus mauritiana*, along with *Sesbania javanica* and *Aeschynomene aspera* on lower lying sites.

Grasses dominate the fields themselves, including *Cynodon* spp. and several identified only by common name (*tkah*, *smaung*, *prawk andauk* and *sluk russei*). These species also cover the bunds which border the fields, although some farmers plant their bunds with clumps of grasses *sbauv* (harvested for roof thatching) and *Vetivera* sp..

Species Richness

Of all 4 LULC classes, the Hillocks class has the greatest observed species richness and the most species unique to that LULC class. As the most prominent topographic features on the floodplain landscape, hillocks themselves are focal points for a diversity of gradients: soil moisture, submergence time, frequency of management activities and disturbances originating from human activity (from plowing at the hillock margin to coppicing for firewood harvest to grazing and trampling of herbaceous groundcover).

This interaction of gradients and management in a diverse environment act to produce many niches filled by a diverse suite of plants. The Ricefield class also maintains a diverse assemblage of herbaceous species. Unlike hillocks, rice fields are topographically uniform. However, they are under a wide variety of management and disturbance regimens: annual cultivation, annual burning, grazing both before and after cultivation, periodic abandonment with herbaceous re-growth. A field may cycle though these different states over the course of one year, or from year to year. Moreover, adjacent fields may or may not follow the same course of land use/land cover change, depending upon how they are managed. This temporal and spatial variation leads to a diverse assemblages of species which fare well under these different micro-environments, many of which are ephemeral.

However, comparison of species richness and diversity among LULC classes is not entirely appropriate. The floodplain environment is patchy and many species are shared across LULC classes. For example, species commonly associated with Shrubland turn up in inventory plots in the Ricefield LULC class because there are small, scattered woodland patches or sparse stands of small diameter stems in some areas classified as Ricefield. Floodplain communities are highly interspersed, with patches and gaps commonplace. In addition to capturing this patchiness, over the course of the inventory it is also possible that some transects crossed from one mapped LULC class into another. These introduce heterogeneity into the data set, to some extent complicating analysis at the community level.

Factors Affecting Floristic Variation Across LULC Classes

Factors which shape the composition of vegetative communities, and thus floristic variation across LULC classes, may be grouped into two categories: biophysical and anthropogenic.

Biophysical Factors Affecting Floristic Variation

These factors are interrelated, all tied into the flood-pulse which governs the region. The interaction of the floods and topography, macro-scale features as well as micro-topography (Vivian-Smith 1997), leads to variation in the amount of time that any one site on the floodplain is submerged annually. Some sites, such as low lying sites, those close to rivers or those closer to the Tonle Sap itself, spend more time submerged than sites closer to the upper edge of the floodplain or hillock sites. Another environmental gradient, related to submergence time, is soil moisture. This parameter is related to location (elevation and topography) as well as soil texture. Some species, such as *Feroniella lucida*, demand better-drained soils, such as sandy soils more common near the upper limits of the floodplain or atop hillocks. Others, such as *Polygonum tomentosum*, demand the year-round moisture of the clayey soils found in depressions. Niches are partitioned based on adaptations to specific edaphic conditions. In some cases, this is seen as concentric rings of mono-specific stands of woody plants around rounded features such as depressions or hillocks, or similarly structured longitudinal bands along linear structures (see Figures 7a-d for examples).

Anthropogenic Factors Affecting Floristic Variation

While biophysical processes set the stage for plant distributions, and operate over longer time-frames, anthropogenic factors are also important. The floodplain has been inhabited, and humans have been participating in floodplain ecological processes, for hundreds if not thousands of years (Stark 2006). However, anthropogenic factors are particularly important as rapidly-acting drivers of change. There are several practices currently in use on the floodplain which impact the composition of plant communities.

Present-day Management Activities

Fire may be one of the most important human-mediated drivers of floodplain plant community composition. With the exception of riparian shrublands and permanent wetlands, much of the floodplain landscape is burned every few years, if not annually. Like savannas in other parts of the world, fire is a major determinant in vegetation structure (Scholes and Archer 1997, Laris and Wardell 2006, Bartlett 2008 [1956]). In the study area, brush fires consume dead grass and small shrubs, while larger shrubs and trees survive. Further, during inventory data collection grassy regrowth from rhizomes and basal meristems was often seen in areas recently burned. Fires are set during the dry season, between the recession of the floods in February and the onset of the rains in April and May. They are set with the understanding that burning will bring fresh regrowth for grazing livestock. Ricefield stubble is also burned during this season to clear the land for subsequent plowing and to return to the soil some of the minerals taken up by the previous rice crop. While it is likely that some fires do escape the fields and enter the surrounding vegetation, the bush fires which affect the majority of the study area are set in separate events. Their burning is not coordinated among land users. Rather, fires are set here and there by individuals as they go about their activities on the floodplain (often fishing or tendng livestock). This can lead to tension, as fire is at odds with the needs of some resource users, such as those harvesting mature grasses for thatching. These tensions generally do not lead to outright conflict. They do however prompt haste, as some scramble to gather resources before the fires are started.

Like fire, grazing is also a major driver in the composition of vegetative communities and likely has been so for a long time. In the present day, grazing is confined to domesticated cattle and water buffalo. However, older village residents recall that the savannas of the Tonle Sap were home at one time to kouprey, feral water buffalo and elephants, though by the 1980s, these had disappeared. Despite the lack of undomesticated grazing species, grazing pressure remains high. Cattle and buffalo graze throughout the landscape (except in ricefields under active cultivation). Even on privately held parcels of land, when the land is not directly under cultivation it is treated as a commonly-held resource in all but the fields closest to the village.

Grazing shapes vegetation in several ways. Most immediately, grazing systems select for plants which tolerate frequent cutting and trampling, such as grass species with durable and rapidly reproducing basal meristematic tissues. It also directly shapes vegetation structure, depending upon the specific landscape on which it occurs. For example, cattle and buffalo open paths and gaps in tall, closed grassland which release woody seedlings in the understory and allow the germination of seeds in the soil. In addition to opening gaps in some vegetation, they also produce thickets in others. Many floodplain shrub species are thorny, which hinders grazing close to their trunks. This allows grasses in the immediate area to grow to maturity (further hindering grazing as mature grasses are less palatable to livestock) and woody seedlings to grow larger, producing thickets of grasses, seedlings and small-diameter shrub stems around clumps of larger woody stems. Thus not only through selection pressure, but also through ecosystem engineering (Jones et al. 1994), grazing animals act on vegetative communities, increasing structural complexity and diversity.

Woody species are also harvested for firewood, for the expansion of ricefields and to a lesser extent for the construction of *samroh* or brushparks (Deap et al. 2003).[12] Over the course of field work, little direct evidence was seen on the floodplain of the harvest of entire trees for either firewood or brushpark construction. There was indirect evidence of floodplain firewood harvest. In the village, it was common to see wagon-loads of trees. However, this wood might have come from either the floodplain or the adjacent uplands, where wood is collected after forest is cleared for the establishment of large-scale plantations. Firewood collection also figured in the oral histories of certain places on the floodplain, generally once wooded but now cleared. Moreover, commonly seen during inventories were the trunk scarring, increased branching and

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12 The brushpark, *samroh* in Khmer, is a structure used in fishing. It is constructed by submerging several entire trees in a cluster, canopy down, and binding them together. The resultant clump serves as shelter for mature fish and fingerlings, which tend to congregate in brushy cover. After a few weeks in the water, the fish around these structures are harvested either by encircling them with a net, removing the trees and then closing the net or more commonly, by using electrical fishing gear which stuns the fish causing them to float to the surface, allowing their rapid collection.

basal suckering resulting from coppicing, particularly of *Barringtonia* and *Stephegyne*. Coppicing is commonly used in firewood collection by both those traveling out from the village for the express purpose of firewood collection, as well as for *ad hoc* cooking fires used by people engaging in other activities.

The construction of brushparks is presently illegal though in previous years they were widely used. Today, they are still seen on lakes far from settlements and roads, where enforcement of environmental laws remains difficult.

Impact of Landscape History

At the onset of the study, landscape history was expected to be an important factor in driving the structure of plant communities. However, aside from the obvious (e.g. ricefields remain ricefields due to annual clearing, burning and tillage), clear trends in succession were difficult to discern. Indeed, some abandoned ricefields and uncultivated grasslands develop into shrublands over time but this is not consistent; some do not. According to both the spatial analysis of change over time (Chapter 2) and oral histories of the area, some sites remain dominated by grasses rather than succeeding to shrubby cover. One possible explanation for this could be fire (Evans et al. 2005, Bartlett 2008 [1956]). Regular burning may slow recruitment of woody species enough to leave the grasses and sedges of the understory with a competitive edge. Moreover, the spatial irregularity of burns may also contribute to the patchiness of the environment, as the landscape is not burned evenly with each fire event.

Despite the multiple successional pathways which complicate linking landscape history with vegetational communities, a few trends may be drawn from the inventory data regarding species distributional patterns:

Gmelina asiatica may be dominant in shrublands of various ages (including the oldest stands in the inventory) as well as in early successional stages of abandoned ricefields and savanna. In areas where it is not the dominant woody species, it is at least present if not common. Generally, *Gmelina* is more dominant at drier sites which were neither atop hillocks nor along rivers. Wetter sites support a more complex mixture of species, with distributions often stratified by soil moisture.

Croton sp. is common in newer shrublands (LULC trajectories **F, *FF), but not in the oldest shrubland in the study area (LULC trajectory FFF). *Hymenocardia wallichii* is common in some recently established stands (LULC trajectories **F, *FF), but not all of them.

Vitex holaodendron is found exclusively in recently established shrubland (under 10 years old). Sites where this species was found were not only recently established, but were poorly drained as well.

Additionally, some trees and shrubs are nearly exclusively planted. These are associated with areas which are currently inhabited or were inhabited in the past. These trees are managed and/or protected because either they are growing on privately owned land, or they are seen as useful to many people, such as the case with shade trees atop hillocks. These species include *Ficus religiosa*, *Albizia saman*, *Tamarindus indica* and most commonly, *Borassus flabellifer*.

A number of species were found to be unique to each LULC class (Table 9). However, without further analysis of the data or additional sampling, it is not possible to speculate as to whether or not these species could be considered “indicator species” associated solely with one LULC class or whether they are simply rare and have yet to be recorded in other LULC classes.

Evaluation of LULC Classification Scheme

While a central goal of this study has been to characterize floodplain floristic associations, an additional goal has been to qualitatively assess the scheme used in the preparation of LULC classification maps discussed in Chapter 2. This scheme was based on a manual interpretation of a digital orthophoto of the study area dating from 2005. This was not exclusively a remote analysis; interpretation was based not only on the visual signatures of landscape elements but also on the author's prior field experience in the area. The ecological data presented here suggest that the LULC classes under their current definition share floristic characteristics which do not allow a discrete separation of LULC classes based *solely* on flora.

In the land use/land cover classification of digital orthophotos, it is necessary to generalize due to the high level of detail in the images. Detail is sacrificed as the landscape is typologized and trends identified. The challenge lies in deciding how much detail to include in the finished product. One choice which must be made is the minimum size of landscape elements which will be mapped, or the minimum mapping unit. In the case of this classification, the minimum mapping unit was 10 m x 10 m. Any landscape patches smaller than that size were incorporated into the surrounding category. This masks some landscape diversity, which can be important in a patchy landscape such as this. These choices are necessary: smaller landscape units are more difficult to reliably identify. This is particularly important when working with lower resolution images. In working with a series of orthophotos, it is necessary to plan the classification based on the lowest resolution image. Similarly, it is not always possible to reliably distinguish between different plant communities. As with minimum mapping units, it is necessary to decide how to categorize and typologize vegetation types. Some generalization is necessary, and some detail is lost. This is an accepted and inevitable part of the mapping process.

An additional consideration is the visibility of certain plant communities in digital orthophotos. Some plant communities are very difficult to discern by eye. For example, it is difficult to differentiate between grasslands dominated by different herbaceous species. This is due to similarity in color, texture and the spatial arrangements of landscape elements. Some floodplain woodlands are also difficult to differentiate, because of similarity in color and canopy structure. Though this is in part compensated for by the context of the feature, atop a hillock or alongside a river, for example. Another feature which is difficult to discern is low density stands of small-diameter shrubs, such as *Gmelina* colonizing a recently abandoned field or field edge. Like the process of generalization, these kinds of features complicate the visual interpretation of orthophotos. However, they are readily apparent in the field over the course of an ecological inventory. The two procedures are therefore complementary, each capturing elements of the landscape which would not be visible were either technique used alone.

Timing of Data Collection

Due to fluctuations in flooding, rainfall and agricultural production, the floristic composition of floodplain communities varies somewhat over the course of the year. The data analyzed in this study were collected between mid-February and early April 2008. This time frame is the narrow window in which data collection is possible without a boat. It is wedged between the recession of the flood and drying of the soil (facilitating access), annual burning of savannas and ricefields (most common in March), the onset of the rainy season (as early as late March or early April) and the initiation of plowing and rice field preparations which follow the Khmer New Year in mid-April (though field preparations are begun sooner at some sites). Paralleling the biophysical calendar, local field assistants are only available during the dry season when local residents are not occupied with cultivating a rice crop. These factors complicate efforts to capture intra-annual floristic variation by performing inventories at different times of year.

Conclusion

Vegetative communities on the floodplain are keenly sensitive to edaphic variation. As one village resident stated in a discussion of the landscape, "*On the floodplain, 10 centimeters make a difference*." Like many other plant communities, the floodplain of the Tonle Sap is dominated by a small number of species, often only one: *Gmelina asiatica*. Remaining species were found to be relatively rare, though community composition varied depending upon land use/land cover type. *Gmelina* itself is regenerating well, with a relatively smooth distribution of diameter size classes. The same cannot be said of *Barringtonia acutangula*, another species important in 3 of the 4 land use/land cover classes examined. Due to heavy harvest pressure, this species is recruiting irregularly.

This flora is shaped by many processes, some long term and slow speed while others act more rapidly in the shorter term. Biophysical factors generally fall into the former category, with long term processes of alluvial deposition, erosion and hydrology shaping the interaction of topography and flooding. The latter category includes anthropogenic factors and recent land use history, including the use of fire and harvest of woody species for firewood and other uses. Though several trajectories of vegetation change were evident, no one successional path was clearly defined. Overall, present day land use and the history of fire were the most important determinants in vegetational community structure.

This study joins a very small number of other studies which examined the flora of the Tonle Sap floodplain through the use of ecological inventory. While some patterns were evident, more research is needed into the interaction between the history of land use, edaphic variation and community structure. Particularly valuable would be research into fire ecology: the dynamics of the annual burns and how different species respond.

Chapter 4

Long Eels to Cook: Natural Resource-Based Livelihood Diversity in a Village on the Tonle Sap Floodplain, Cambodia

អន្ទង់វែង កុំបាច់រកឆ្នាំងវែង ៗ

> *“Just because you have a long eel [to cook] doesn't mean that you need to look for a long pot to cook it in.”* – Khmer proverb.
>
> *“...in dynamic environments the survivors are those that rapidly adapt, not those who specialize too narrowly.”* – Niemeijer 1996:93, quoted in Adams and Mortimore, 1997:158.

Introduction

Central to this research project has been the question of how people shape floodplain plant communities through their daily activities, and the converse, how plant communities shape peoples' daily activities. In Chapter 2, an analysis of the historical and present day spatial organization of the landscape was presented. A land use/land cover (LULC) classification scheme was also introduced, around which the remainder of the study is organized. This addressed the "where", "when" and in some cases "why" of floodplain plant communities. To expand into "what" constitutes these plant communities and "how" these are changing, Chapter 3 presented an analysis of an ecological inventory of the plant species which grow in that landscape by describing plant communities which are associated with the LULC classification scheme outlined in Chapter 2. Both chapters discussed dynamics of change, spatial and floristic, as well as historical and present-day land use processes which shape these dynamics. This fourth chapter adds a new layer to the discussion of this landscape, further plumbing the "how" of plant community dynamics by presenting an analysis of written surveys presented to village residents which focused on land use and activities which directly shape the landscape. As with the discussion of landscape structure and plant communities, this analysis is organized around the LULC classification scheme, with survey respondents answering questions framed by the different LULC classes.

Studies which examine the details of human-landscape relationships by focusing on natural resource-based livelihoods have a long tradition in ecology, geography and anthropology. But such a focus has also arisen in other fields, including ethnobotany, economics, rural sociology, and development studies. While each field uses different points of reference, scales of observation, analytical tools and theoretical constructs, all share the common thread of examining what people are doing in their day to day lives and how this shapes, and is shaped by, the landscape. This study shares this focus, albeit with a *plant-based* livelihoods bent. Where it differs from many others is in the deliberate use of an interdisciplinary methodology, informed by spatial (Chapter 2), ecological (Chapter 3) and social (the current chapter) approaches, to dissect patterns and relationships.

The present chapter defines the contours of the diversity of one sector of village livelihoods-- those which are based on the production, management and extraction of natural resources. This livelihood typology does not focus on the differentiation between on-farm, off-farm or non-farm economic activities (Ellis 1998) or upon how households are situated with respect to merging rural and urban markets (Rigg 2006). Instead, a typology based upon landscape is applied. In emphasizing spatio-temporal relationships implicit in the dynamic floodplain landscape, rather than an economic domain (subsistence vs. market, productive vs. consumptive) or a market (urban vs. rural, formal vs. informal), the focus remains the production of landscape as the physical manifestation of the multi-scalar biophysical and social processes which govern human activities on the floodplain.

As Scoones (2009) points out, the application of the word "livelihood" in research is fluid. Attaching it to various modifiers yields different fields guided by different questions, covering territory as diverse as locale (e.g. *rural* livelihoods), occupation (e.g. *agricultural* livelihoods) and dynamic processes (e.g. *sustainable* livelihoods) (Scoones 2009:172). Despite this semantic breadth, the livelihoods approach remains rooted in pursuing an understanding of people's "means of gaining a living" (Chambers and Conway 1992:5). It is in this spirit that the present study embraces the term. However, the methodological approach used here owes more to the study of agrodiversity (*sensu* Brookfield and Padoch 1994). Broadly referring to the diversity within and among production systems, agrodiversity as an analytical framework encompasses several different facets of production system diversity (Brookfield 2001): agrobiodiversity (which includes domesticated and semi-domesticated or managed useful species), biophysical diversity (which includes soil characteristics, as well as animals and spontaneous plant life), management diversity (which includes the knowledge and techniques used in agricultural production) and organizational diversity (which includes timing and labor allocation as well as broader, household-level management of capital and assets).

Central to the framework is appreciating the dynamism inherent in land management and production systems. More than just a philosophical leaning, it is reflected in the very language of the objects of study. For example, the coarsest scale of landscape organization used in this framework is the land use stage (Brookfield et al. 2002, Brookfield 2001). While the land use stage maps neatly onto the well-established concept of the land use/land cover class, connotations of dynamism are built into the term which suggest that the landscape element under analysis is only a step in an on-going, but not necessarily teleological, process (Padoch et al. 1998). Likewise, the natural resource-based livelihoods discussed herein are not merely static lists of past events. They are snapshots of the dynamic processes of “gaining a living” as embodied in the livelihood portfolio. In a sense, they are the negative of aerial photographs of a landscape. Aerial photographs capture the landscape at one point in time; the composition and structure of the landscape at that time is reflected in the livelihood portfolios of the households making their living in that landscape. Likewise, a list of livelihood activities captures a household's livelihood portfolio at one moment in time; its composition and structure reflect the landscape in which the household is embedded.[13] As such, retrospective free-listing of livelihood activities is one method to elucidate these relationships between livelihood portfolios and landscape.

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[13] The purpose of this analogy is to highlight the dynamism concealed in a seemingly static list. It is not meant to exclude higher-orders of biological and social organization. While embedded in a physical landscape, the household is also embedded in multiple networks of social relationships, power relationships and governance. While these relationships are acknowledged, they are not the primary focus of this component of the study, where a “somewhat limited” perspective on livelihoods and landscape is employed (Netting 1993:262).

Regional Background

Discussions and analysis of rural livelihoods in Cambodia are diffuse. Certain historical moments have been better documented than others, with lacunae stretching hundreds of years in between. Some of the earliest descriptions of rural life in Cambodia are seen in the narratives of travelers, traders and political emissaries who traveled to Cambodia at various points before the establishment of the French Protectorate in 1863. Among the earliest of these narratives is the account of Zhou Daguan, a Chinese political emissary who lived in Cambodia from August 1296 to July 1297 (Zhou 2007). Later accounts include those of Spanish and Portuguese merchants, clergymen and soldiers (Groslier 2006). While both include observations about village life and agriculture (the latter includes much derring-do, as well), neither focus exclusively on either land use or the Tonle Sap floodplain. While not expressly focused on the Tonle Sap, Thorel (2001 [1873]) is among the first researchers to systematically explore plant use and agriculture in the region, which is detailed in a report to the Mekong Expedition Commission.

The French Protectorate Period is marked by scattered reports by colonial governors and planners. The most comprehensive work to arise from this period, indeed among the most comprehensive work on Cambodian rural livelihoods to date, is Delvert's "*Le Paysan cambodgien*" (1994 [1961]). Rich in descriptions as well as data sets, he addresses topics from geography and climate to social organization and production systems.[14]

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[14] Delvert also includes a description the geography and livelihoods of Srayov Commune in Kampong Thom Province, where the study site is located (Delvert 1994[1961]:620)

The period prior to the civil war is marked with another burst of activity from French researchers in the fields of ethnobotany (Vidal 1971; Martin 1969, 1971; Martel et al. 1969) and the study of vernacular nomenclature (Lewitz 1967, for toponyms; Lewitz and Rollet 1973, for plant names). There was little village-level research published in English during this period. Kalab (1968) described social structure and political organization in a village in Kampong Cham. While particularly notable is the doctoral dissertation of May Ebihara (1986). Based on fieldwork in Kandaal Province, hers is the only completed English language ethnography from the period prior to the civil war. Research during the civil war years and the genocide perpetrated by the Khmer Rouge was confined to political analysis from afar.

Local-level research did not begin anew until the arrival of international aid agencies in the early 1980s, in response to the post-genocide devastation of the country and the famine which followed the toppling of the Khmer Rouge in 1979. Many of these reports focus on development and poverty alleviation in light of the the poor condition of the country's production systems and the vulnerability of the Cambodian population (Mysliwiec 1987, 1988; Pijpers 1988, 1989; Dennis 1979). Though not as broad in geographic scope as Delvert's work, Tichit's "*L'agriculture au Cambodge*" describes dominant agricultural production systems, the production of minor crops such as spices and fiber plants, and also the management of useful forest plants, including rattans and the resin-bearing *Dipterocarpus* (Tichit 1981). This period is marked by the emergence of gray literature produced by development agencies, and a scarcity of research published in peer-reviewed journals. Though notable exceptions include Grunewald's (1993) description of agriculture, fisheries and the floodplain landscape at the end of the civil war and Martin's (1981) discussion of rice production and irrigation systems under the Khmer Rouge. Additionally, Than's (1982) thesis describes the history of Cambodian irrigation technologies from ancient structures through more recently constructed systems. He also includes a discussion of local knowledge of small-scale water management, the construction of “indigenous dams” (Than 1982:67-75) and manual technologies for moving water (Than 1982:82-87).

Some of these publications began to reflect the emergence of the Livelihoods Approach in the field of development studies which occurred in the mid-1990s (Shams and Hong 1998, Keskinen 2002, McKenney and Tola 2002, Baltzer et al. 2003, *inter alia*).[15] This period is also characterized by further sectoral specialization among publications, in for example fisheries (e.g. Lamberts 2001; publications of the Mekong River Commission), or agriculture (e.g. Nesbitt 1994 and other publications of the Cambodia-IRRI-AusAid Program),[16] as development agencies became entrenched and local government authorities more stable.

The return of civil stability in the late 1990s saw the resumption of scientific research in Cambodia. Some of this work focuses somewhat broadly on rural livelihoods (Ledgerwood 1998, Marschke 2006, Keskinen 2006, Diepart 2010). However, much of

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[15] See Scoones (2009) and, De Haan and Zoomers (2005) for more on the history of the Livelihoods Approach.

[16] Cambodia-IRRI-AusAid Program (CIAP) was renamed the Cambodian Agricultural Development Institute (CARDI) in 1999 when it became an independent Cambodian government research center.

this work approaches the study of livelihoods as they relate to particular species or products of interest (deepwater rice cultivars, Pel 2002; snakes, Brooks et al. 2008; the Bengal florican, Evans et al. 2005; non-timber forest products, Baird 2010). The present study nests in this final category, due to the focus on natural resource-based livelihoods at the expense of information about non-farm activities.

Methodology

A survey was designed to elicit information regarding the spatial partitioning of the natural resource-based livelihood activities of village residents by focusing on the relationships between natural resource-based livelihood activities and the LULC classes in which they are performed (both Khmer and English versions of the survey are included in the appendix). To do this, informants were asked about each LULC class separately.[17] For each LULC class, they were asked to free list their "everyday livelihood activities" (Bernard 2006).[18] Ancillary information regarding those activities mentioned was also collected, for example whether or not collected natural products were sold. Questions were also included regarding specific activities which overtly shape the LULC classes discussed, such as tree planting, land clearing and the digging of ponds. Lastly, informants were asked to compare natural resource use between the present (then April 2009) and both five years ago and "difficult years." These final questions were included to gain insight into mechanisms of resource management flexibility and into processes of change in the local environment. The survey was

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[17] Land use/land cover classes were in part designed based on local categories for landscape features.

[18] The survey used the idiom, “រករបរសំរាប់ចិញ្ចឹមជិវិតប្រចាំថ្ងៃ" meaning roughly “to seek occupations necessary for daily sustenance.”

written in Khmer by Roberts, then edited for clarity by a literate, native speaker with experience in the use of surveys to study rural livelihoods.

Based on previous fieldwork in the village, a sample size ranging from 25 to 50% of village households was judged to be large enough to adequately capture the diversity of village livelihoods (Bernard 2006). Families were randomly selected from a village census conducted in 2005. At that time, the village numbered just over 500 households. In the intervening years, no new census had been performed. As of 2009, it was still the best available source of information about village residents. Though due to the age of the census and the lack of a current family list, newly established families and recent arrivals from outside the village were not included in the sample.

For data collection, a survey administration team of 10 individuals (5 male, 5 female) was assembled with the assistance of the director of a local NGO. All were educated Khmer professionals who worked as teachers, agricultural extensionists or in economic development. All lived in Kampong Thom Province, though none were village residents. Prior to the start of data collection, the team was given a 3-hour long orientation to the research project, data collection methods to be employed, as well as the content and structure of the survey.

Working in pairs (one male, one female), the survey administration team circulated through the village, each with a list of individuals selected to be interviewed. Respondents were located with the help of village elders and other village residents. Most interviews took place in the homes of the respondents between the hours of 0700 and 1600. Answers to the survey were handwritten on data sheets by the interview team, with one of the pair asking questions and the other recording responses.

Survey results were first translated back into English by Roberts (with the help of a native speaker for surveys with difficult to read handwriting) then coded into an OpenOffice Base database. Subsequent statistical summaries and linear correlation analysis were performed using OpenOffice Calc.

Two-hundred thirty-four families were interviewed. Data from the first 121 families are presented here, representing approximately 25% of the village and a mix of surveys collected by all 5 data collection teams. Adequate for sampling purposes, these data capture the bold trends in land use, as well as the diversity of less common activities which fill out each family's natural resource-based livelihood portfolio. The remainder of the data will be presented in a subsequent publication.

Results and Discussion

Spatio-temporal Partitioning of Livelihood Portfolios

Table 10 presents the list of natural resource-based livelihood activities which were reported in the survey. The table is similar to a relevé table, often used in plant community ecology (Mueller-Dombois and Ellenburg 1974; see Chapter 3 for further discussion of relevé tables). Here, the frequencies for each activity being performed in each LULC class were organized first by the number of LULC classes in which they were reported. Then the data were organized by the frequency for which each was reported for each LULC class. This scheme emphasizes the relationships within and among LULC classes.

These data do not just reflect the responses of the survey participants. They also reflect the way in which both livelihood portfolios and the landscape are partitioned in space. Activities performed in fewer LULC classes are more strongly spatially partitioned, tied to a smaller number of landscape features, than activities more widespread among LULC classes. This partitioning is related to both the landscape and the organisms which inhabit it.

The features which comprise the floodplain landscape vary in their degree of interspersion. For example, much of the savanna is dotted with small ponds and seasonal wetlands which grade into the surrounding cover through gentle changes in elevation. Thus the Waterbody LULC class is not highly spatially partitioned. Accordingly, the livelihood activities associated with it are not highly spatially partitioned. They are performed across multiple classes.

The opposite may be said of the Hillock LULC class. Hillocks, while widely scattered on the floodplain, are less common than waterbodies. Lacking the fuzzy boundaries of waterbodies, their edges are more discrete, marked up a dramatic elevation change. As landscape elements, they are strongly spatially partitioned. Likewise, the activities performed in the Hillocks class share that degree of spatial partitioning, evident in the number of livelihood activities unique to that class. Figure 10 graphically represents the proportion of the total number of responses for each livelihood activity which correspond to each LULC class.

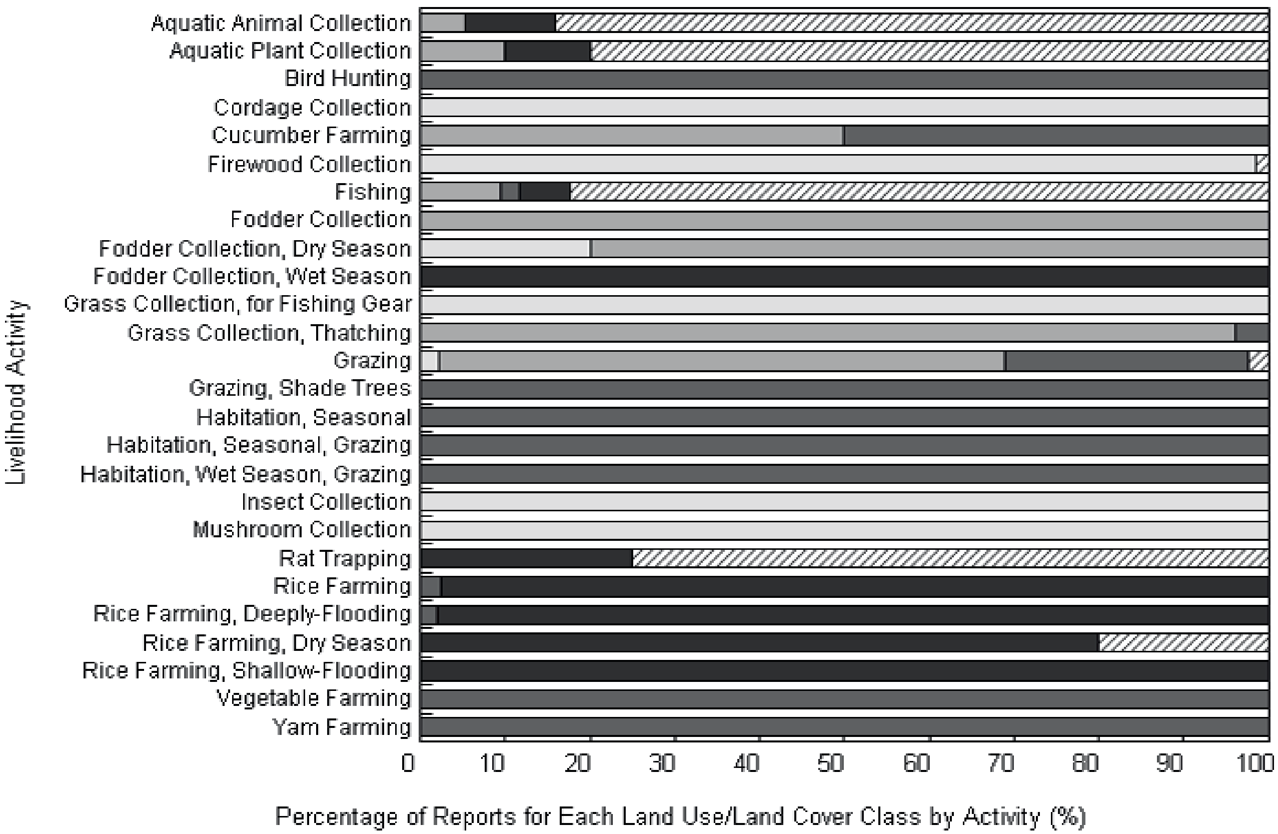

Figure 10. Proportion of land use/land cover classes reported for each livelihood activity. For this survey, respondents free-listed livelihood activities which they performed in each of five land use/land cover (LULC) classes. Some livelihood activties were confined to only one LULC class, while others were performed in more than one (n= 121). The degree to which an activitiy is associated with a particular land use/land cover class reflects how spatially partitioned that activity is. For example, activities taking place most frequently in only one land use/land cover class, indicated above bar an unbroken bar, would be considered spatially partitioned activities. While more widespread activities would be considered less spatially partitioned.

□ Shrubland ▨ Grassland ■ Hillock ■ Ricefield

The interspersion of the landscape is additionally the reason for seemingly incongruous pairings of activities and LULC classes, such as fishing reportedly performed in the Grassland class. In this case, fishing occurs both in small seasonal and permanent ponds situated in the grassland, as well as over entire grassland areas when the floods are up and the landscape is under 1-3 meters of water.

Each LULC class is characterized by one or two livelihood activities (or activity categories in two cases) which dominated the reports for that particular LULC class and occurred infrequently elsewhere. These characteristic activities are also the most widely reported for all LULC classes (Figure 11).

The most common activity in the Shrubland class is firewood collection. Collection of grass for thatching was most widely reported in the Grassland class, followed by the grazing of cattle and water buffalo. Various forms of settlement were the most commonly mentioned land uses in the Hillock class. Land use in the Ricefield class is dominated by the class's namesake, rice farming, while fishing typifies the Waterbody class. Other activities were much less frequently reported (Figure 11).

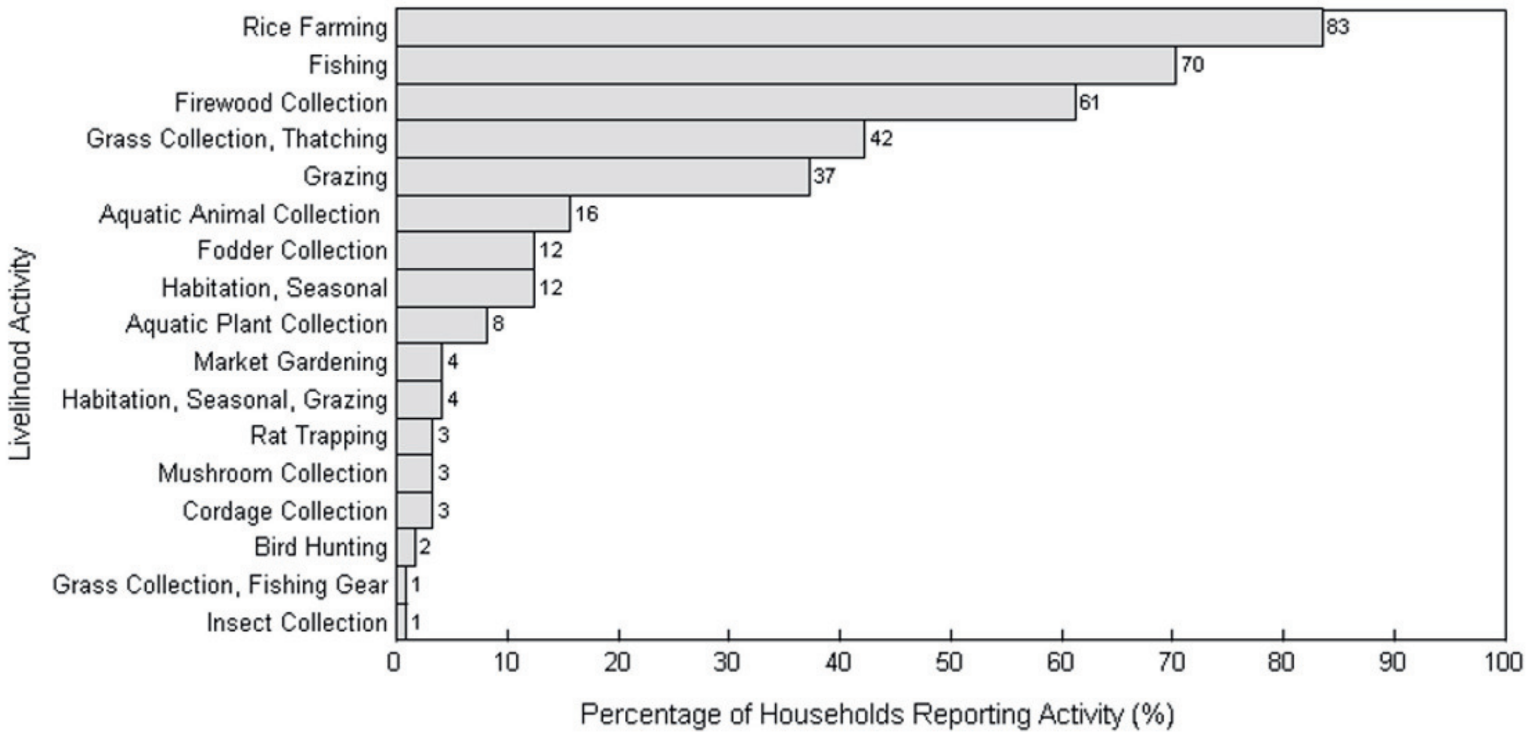

Figure 11. Percentage of households interviewed which participate in each natural resource-based livelihood activity, pooled across all 5 land use/land cover classes (n= 121).

Several related livelihood activites were lumped together in order to enhance chart clarity: Fodder Collection (aggregation of Fodder Collection; Fodder Collection, Dry Season and Fodder Collection, Wet Season), Grazing Camp (aggregation of Grazing Camp; Grazing Camp, Wet Season and Grazing, Shade Trees), Rice Farming (aggregation of Rice Farming; Rice Farming, Dry Season; Rice Farming, Deeply Flooding; Rice Farming, Shallow Flooding) and Market Gardening (aggregation of Vegetable Farming, Yam Farming and Cucumber Farming).

Table 10. Frequency that each natural resource-based livelihood activity was reported by survey participants for each land use/land cover (LULC) class. Activities are ranked first by the number of LULC classes in which they were present (# of Classes), then by frequency within land use/land cover class (n=121). Seasonality is reported here only for those activities for which a specific season was reported by survey respondents.

	Land Use/Land Cover Class					
Activity	Shrubland	Grassland	Hillock	Ricefield	Waterbody	# of Classes
Grazing	1	30	13	0	1	4
Fishing	0	8	2	5	70	4
Aquatic Animal Collection	0	1	0	2	16	3
Aquatic Plant Collection	0	1	0	1	8	3
Firewood Collection	73	0	0	0	1	2
Fodder Collection, Dry Season	1	4	0	0	0	2
Grass Collection, Thatching	0	49	2	0	0	2
Cucumber Farming	0	1	1	0	0	2
Rice Farming, Shallow-Flooding	0	0	1	49	0	2
Rice Farming	0	0	1	41	0	2
Rice Farming, Dry Season	0	0	0	4	1	2
Rat Trapping	0	0	0	1	3	2
Cordage Collection	4	0	0	0	0	1
Mushroom Collection	4	0	0	0	0	1
Grass Collection, for Fishing Gear	1	0	0	0	0	1
Insect Collection	1	0	0	0	0	1
Fodder Collection	0	9	0	0	0	1
Habitation, Seasonal	0	0	15	0	0	1
Habitation, Wet Season, Grazing	0	0	3	0	0	1
Grazing, Shade Trees	0	0	2	0	0	1
Bird Hunting	0	0	2	0	0	1
Vegetable Farming	0	0	2	0	0	1
Yam Farming	0	0	1	0	0	1
Habitation, Seasonal, Grazing	0	0	1	0	0	1
Rice Farming, Deeply-Flooding	0	0	0	4	0	1

The correlations between the most widely-reported livelihood activities for each LULC class were in-part to be expected, as the LULC classes were designed to take dominant land use into account. This represents the spatial partitioning of livelihood activities across the landscape. Combining these data with observations and interviews accumulated over nearly 2 years of village-based fieldwork also reveals a temporal partitioning of these activities, generally between the wet and dry seasons. While there is overlap between LULC classes and activities, several of the dominant livelihood activities are confined to a particular time of year (Figure 2). Firewood collection occurs either at the peak of the dry season after the recession of the floodwater (February to March) or at the peak of the flood season (October to November). At these times of year, transportation is easiest. Collection of grasses for thatched roofing and sale is performed at the peak of the dry season (February to March). The season may be curtailed early if the brushfires which sweep the savannas annually are started early or spread more rapidly than usual. Grazing in the Grassland class occurs throughout the dry season and early wet season, beginning in December or January with the recession of the floods. Water buffalo may also graze in these areas through the wet season, but cattle are usually herded upland off of the floodplain at that time. Hillocks serve as camp sites year-round for families who are engaging in activities on adjacent land, such as tending livestock, cultivating rice or fishing. Rice production typically begins with the onset of the rains in late April or May, the production season running from 3-6 months or more, depending upon the varieties of rice being produced. Small-scale dry season rice, a minority production system in areal terms, is produced during the dry season starting as soon as the floodwater recedes Some families engage in fishing year-round. However the most productive season for fishing is the beginning of the dry season immediately following flood recession. At that time, seasonal depressions around the floodplain will be filled with water and populated with fish left stranded by the receding floodwater.

Diversity of Livelihood Portfolios

The diversity of livelihood activities and LULC classes utilized is summarized in Figure

12. Two frequency distributions based on survey responses are shown: the frequency of total numbers of livelihood activities per household, and the frequency of total numbers of land use/land cover classes utilized per household.

Ranging from 0 to 10, the most commonly reported number of activities per household was 5, while the median number of activities was 4 (for additional descriptive statistics, see Figure 12). The number of land use/land cover classes used by each household ranged from 0 to 5, with 4 classes being most commonly reported. The median number of classes was 3. In order to explore how these variables might be related to each other, the data were log transformed to bring them closer to a normal distribution (Zar 1999). A linear correlation analysis was then performed which showed highly significant correlation ($r^2 = 0.89107$, $p < 0.001$) (Figure 13).

These data indicate that in 2009, most households utilized a relatively diverse portfolio of natural resource-based livelihood activities from which they drew sustenance, both nutritional and financial. That half of the reporting households utilized 3 or more different LULC classes also indicates landscape diversity is important to households in Roka Village.

Rather than specializing in a single-sector natural resource-based livelihood as farming, fishing or livestock keeping, most households juggle several different activities which are performed at different times of year and utilize different portions of the landscape. Permutations of both arrangements have been reported elsewhere on tropical floodplains and lake shores: single-sector specialization (for Danau Sentarum National

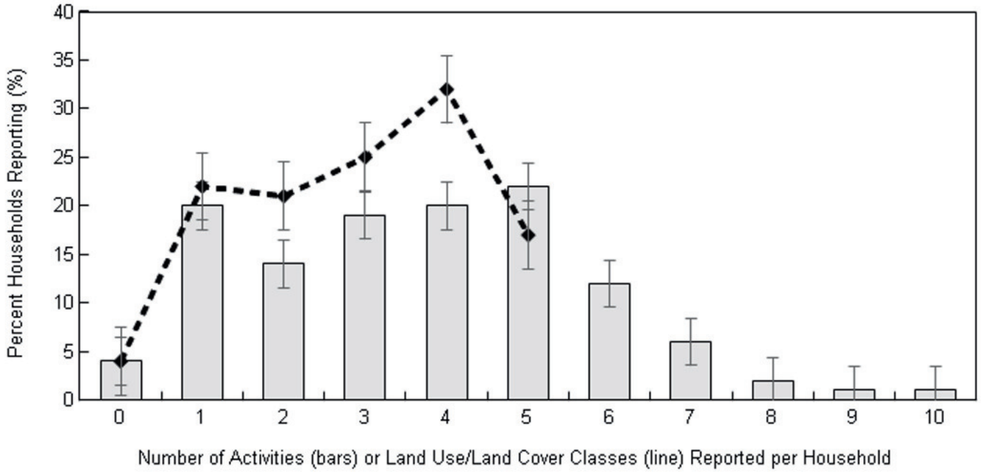

Figure 12. Total numbers of natural resource-based livelihood activities per household and land use/land cover (LULC) classes utilized per household. Total number of livelihood activities per household for all 5 LULC classes in aggregate are marked by the vertical bars (n= 121, mean number of activities engaged in= 3.67, median= 4, mode= 5, range 0-10, SD= 2.09, SE= 0.19). Total number of LULC classes utilized per household is marked by the broken line (n= 121, mean number of LULC classes utilized= 2.91, median= 3, mode= 4, range 0-5, SD=1.43, SE= 0.13). Data points from both sets include standard error bars.

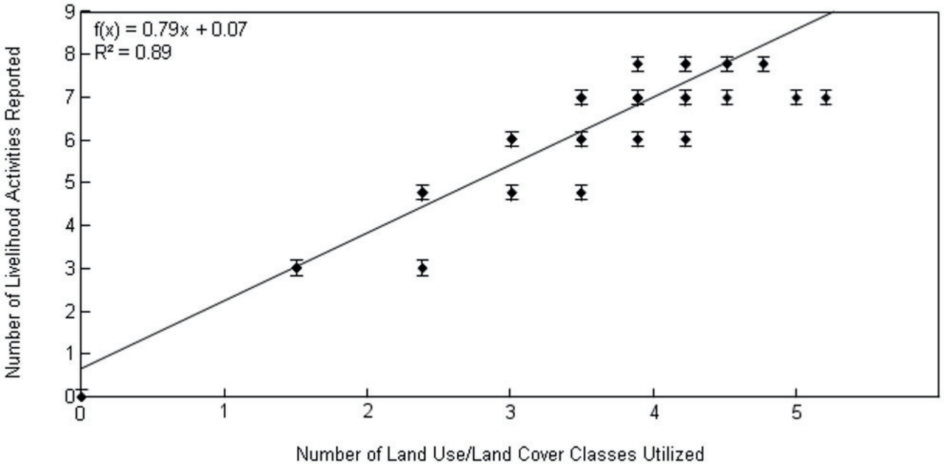

Figure 13. Linear correlation analysis of the total number of natural resource-based livelihood activities reported by each household (y-axis) and the total number of land use/land cover classes utilized by each household (x-axis). Prior to analysis, data were log transformed ($x'=\text{Log}_{10}(x+1)$, Zar 1999). Data points are marked with standard error bars. Based on this analysis, there is a highly significant relationship between the number of livelihood activites reported by a household and the number of land use/land cover classes utilized by a household (n= 121, r^2= 0.89107, r= 0.94397, p<0.001, SE= 0.03026).

Park, Indonesia, Colfer et al. 2001; for Logone floodplain, Cameroon, Moritz et al. 2010) and multiple-sector specialization (for the Tonle Sap floodplain in Pursat Province, Cambodia, Shams and Ahmed 1996; for the Amazonian v*árzea* , Peru, Pinedo-Vasquez and Sears 2011; for Lake Victoria, Kenya, Geheb and Binns 1997). That the activities of residents of the Tonle Sap floodplain are both temporally and spatially partitioned makes this livelihood diversity possible.

Livelihood diversity has been highlighted as an important factor in the mitigation of risk (Evans 2009, Rigg and Salamanca 2009, Brookfield 2001, Batterbury 2001, Ellis 1998, Adams and Mortimore 1997). Dependence upon many different natural resources allows households to compensate for challenges or to take advantages of opportunities by shifting labor and resources from one activity to another. This is facilitated here by the temporal partitioning of livelihood activities, spreading out labor demands across the calendar and minimizing labor scheduling conflicts (Stone et al. 1990).

The correlation between number of livelihood activities performed and the number of LULC classes utilized also suggests that livelihood flexibility, nimbleness or adaptability with respect to external change (Bouzarovski 2009), is at least in-part dependent upon landscape diversity. As such, changes in landscape diversity have an effect on household flexibility. In a comparative analysis of livelihood flexibility in communities along a gradient of agricultural intensification on the Nigerian Sahel, Adams and Mortimore (1997) describe 6 dimensions of flexibility in production and livelihood management systems: flexible use of farm labor, flexible use of cultivar diversity, flexible use of economic plants, flexible use of grazing resources, flexibility in field location, and flexibility in livelihood strategies. Under conditions of a simplifying landscape, it is likely that all facets of flexibility save perhaps the flexible use of farm labor would be negatively affected (and even that might be affected if the community undergoes a shift away from agricultural production towards wage labor). This would leave households more vulnerable to shocks and less able to exploit new opportunities (Evans 2009, Ellis and Allison 2004). A heterogeneous landscape, in contrast, would yield the opposite effect.

Factors Driving Change: Challenges, Constraints and Processes

Survey respondents were given two opportunities to discuss the differences in natural resource-based livelihoods between the year of the survey (2009) and the past. One question focused on recent history (5 years prior), a second question addressed the more subjective, “difficult years.” By and large, respondents listed various production challenges and perceived problems in the form of reasons why one time period was more difficult than another. The three most commonly cited challenges are listed in Table 11.

Table 11. Relative frequencies of the three most frequently cited household challenges for each land use/land cover (LULC) class. Of the 121 households surveyed, total number of challenges reported varied by LULC class: Shrubland, 137; Grassland, 128; Hillock, 14; Ricefield, 115; Waterbody, 130. For the Hillock LULC class, each of the 14 challenges mentioned were different. As there were no predominant results, they are not listed here.

LULC Class							
Shrubland		Grassland		Ricefield		Waterbody	
Challenge	Rel. Freq.	Challenge	Rel. Freq.	Challenge	Rel. Freq.	Challenge	Rel. Freq.
Forest loss	25.55	Agricultural development	17.19	Unusually high floods	42.61	Use of electrical fishing gear	22.31
Agricultural development	15.33	Privatization of land	16.41	Drought	15.65	Increased number of harvesters	16.15
Population increase	10.22	Unusually high floods	12.50	Low soil fertility	11.30	Diminishing fish stocks	15.38

The challenges cited by survey respondents fell roughly into three categories: personal obstacles (e.g. illness), historical events (e.g. unusually high flooding) and processes or conditions reflecting processes (e.g. low soil fertility, increasing village population). For the most part, the most widely reported challenges to households were processual. Though droughts and unusually high floods, episodic events, were also mentioned with respect to activities in the Grassland and Ricefield LULC classes. Overall, processes related to the expansion of large-scale dry season rice production figured prominently as areas formerly held in common are privatized, enclosed and developed at the expense of road networks, savannas and shrubland (for a more detailed discussion of this phenomenon, see Chapter 5). Also widely cited with respect to fishing activities in the Waterbody LULC class is the expansion of the use of illegal, electrical fishing gear which allows larger catches with less effort when compared with other fishing gear. Harvesting mature and juvenile indiscriminately, electrical fishing gear are popularly credited with overfishing and decline of fish populations. Increasing village population, increasing competition over resources and other population-related challenges were also frequently mentioned. Reports by survey respondents echo many interviews performed at other points over the course of this research project.

Generally, these challenges resulted in decreased harvest of the product in question, or of an increased effort in order to maintain harvests similar to those of the past. Only a few respondents stated that they had abandoned particular livelihood activities due to the reported challenges. No one reported adopting a different activity in order to replace a more difficult activity. In addition to providing information on how change is experienced by household members, the challenges themselves present evidence of the manner in which households are embedded in higher-order processes. They indicate connections across scales (Wilbanks and Kates 1999).

Taken at their face value, the challenges reported by survey respondents are comparable to lists of constraints on production used in agronomic research to prioritize hindrances to maximum agricultural production. This reading denies feedback loops and the embeddedness of the survey respondents who, willing or not, are participants in these processes and whose behaviors change in response to the very processes which they discuss. Moreover, viewing them as constraints on production also downplays the importance of processes acting across scales of biological and social organization, bridging hierarchical levels (Allen et al. 1984). While this might appear to be semantic quibbling, approaching these data as *processes* rather than *constraints* brings feedback loops and cross-scalar relationships into sharper focus (Padoch et al. 2008:141). Viewed with such a processual orientation, this set of survey data is valuable as a set of suggestions for future avenues of inquiry into the drivers which are affecting livelihood change and landscape change.

Conclusion

The floodplain of the Tonle Sap is a complex and dynamic landscape, characterized by the floodpulse which annually transforms savannas and shrublands into a vast lake. This landscape has been inhabited for centuries, if not millenia (Stark 2006), not *in spite of* this complexity but rather *because of* this complexity. Floodplain residents do not specialize in any one natural resource-based livelihood, as farmers, fishers or herders.

In contrast, they maintain a diverse portfolio of livelihood options best positioning them to utilize a broad range of natural resources. This diversity directly correlates with landscape diversity: the more diverse the livelihood portfolio, the wider the variety of landscape units utilized by the household. Partitioned in space through the utilization of different land use/land cover types, livelihood activities are also partitioned in time, as many occur at different times of year. By understanding and managing of this partitioning, floodplain residents are able to utilize a wide variety of natural resources which both mitigate household risk and also provide potential for new opportunities. The flexibility which comes with livelihood diversity is dependent upon landscape diversity. With loss of access to the landscape, through either privatization and enclosure or through simplification of the landscape and land use/land cover change, this flexibility is threatened. However, improvisation figures highly in the skillset of people who gain a living in such a dynamic environment. The evidence of this is seen physically inscribed upon the landscape by a diversity of livelihood activities which utilize a diversity of ecological and economic niches. It is also evident in Khmer culture. As the proverb at the beginning of this chapter points out, the obvious path is not necessarily the only path.

Chapter 5

The Hillock-Depression Complex: Illegible Landscapes and Land Use in Spatio-Temporal Context

Introduction

The upper reaches of the Tonle Sap floodplain in central Cambodia are among some of the most productive agricultural land in the country. However, the annually flooding savannas closer to the lake itself have reportedly been called wastelands by government officials encouraging their development. Floodplain land use policies have reflected this attitude. The return of security to the floodplain following the demilitarization of remaining Khmer Rouge soldiers in the late 1990s, has seen rapid development. In recent years, large scale dry season rice farms have expanded and petroleum exploration has begun. These developments have taken place with little consideration for how these changes might affect the lives of local residents who depend upon the resources of the floodplain. In order to equitably plan the management of natural resources, it is necessary to first grasp the diversity of the resources available and their importance to the various stakeholders involved (Walker et al. 2003). In the case of the Tonle Sap flooding savannas, these questions have been overlooked.

The grasslands and wooded savannas that comprise the floodplains are often glossed as "flooding savanna" or even simply "grasslands" (McDonald et al. 1997, Delvert

1994). While the use of this category is not inaccurate-- the floodplains between the deeply flooding forested areas fringing the Tonle Sap and the uplands further from the lake are indeed covered by open grasslands and wooded savannas-- the use of this single category masks the diversity of plant communities and landscape features on the floodplain, giving an impression of a homogeneous environment while concealing the diversity that makes this area so productive. It likewise obscures the handprints and footprints of populations of fishers, farmers and livestock-keepers who have made their lives on the floodplain for more than 1000 years (Stark 2006, Fox and Ledgerwood 1999).

Topographically, the floodplain may be characterized by a gradual downward slope toward the Tonle Sap lake. But, small-scale topographic features abound. In many areas the floodplain is punctuated by hillocks, ridges, depressions, ponds, streams, and more. However, this landscape diversity is not legible from smaller scales, either geographic or governmental (Scott 1998). The 1:50,000 topographic maps prepared by the US Army Topographic Command in 1971 allude to a diverse landscape by noting "numerous small and intermittent ponds" in some areas. However many of these landscape features rise or fall as little as a meter or two from the surrounding landscape, and are so subtle as to be invisible on currently available topographic maps or digital elevation models. Despite their apparent subtlety to outside observers, local residents have detailed understandings of these landscapes, managing them through many different productive and extractive activities (Brookfield 2001, Ellen et al. 2000, Netting 1993).

One of the many landscape features found on the floodplain is what will be termed here the *hillock-depression complex (HDC)*. These poorly-characterized associations of small hills and adjacent depressions play an important role in many floodplain livelihood activities. For this reason, the HDC will be explored here as a case study to explore the diversity of floodplain landscapes and how this diversity relates to local livelihoods and land use illustrating how a fine-grained understanding of the landscape is important in equitable natural resource management.

Floodplain Livelihoods

The people who live on the Tonle Sap floodplain maintain a diverse portfolio of livelihood strategies (Diepart 2007, Keskinen 2006, Balzer 2003, Delvert 1994 [1961]). Dominant activities for many families include farming rice, fishing, and herding cattle or buffalo, depending upon the season. The floodplain is the site of many other activities, including both plant extraction (e.g. cutting firewood or gathering grasses for roof thatching) and animal extraction (e.g. collecting snakes and small birds for sale). As with elsewhere in the region, many families also take advantage of some off-farm income generating activities through wage labor or small commerce (Rigg 2006). These many productive and extractive opportunities on the floodplain thus allows households to develop a diverse *productive bricolage*, engaging in different activities depending upon available labor and resources (Croll and Parkin 1992, Batterbury 2001).

Diverse land use portfolios are vital for household survival in dynamic environments (Carr and McCusker 2009, Ellis 2000, Ellis 1998, Adams and Mortimore 1997). The Tonle Sap floodplain is a very dynamic environment, both politically and ecologically, and at a range of temporal scales. Within the memory of the oldest residents of floodplain villages, Cambodia has seen five different national flags and over 30 years of war and civil unrest. Cambodia's economy has shifted from a centrally planned to a market economy, expanding and contracting rapidly in recent years. Throughout these structural changes and the uncertainty they have brought, village residents have capitalized on the resources of the floodplain, taking advantage of opportunities and mitigating risk.

In addition to the longer term view of dynamism, the Tonle Sap flood cycle fluctuates from year to year. With the rise of floodwaters during the rainy season, the terrestrial landscape becomes an aquatic landscape. Hillocks become islands of dry land when the surrounding landscape is flooded. During the dry season, depressions form ponds or wetlands punctuating the arid landscape. From year to year, there is great variation in flood height, flood rate, rainfall and other factors that shape resource use decisions of local residents.

This annual ecological variation is a factor in the development of a diverse landscape. Hillocks and depressions act as vegetation islands. Some are islands of woody plants when the surrounding landscape is dominated by grasses, for example. Slight elevational difference from the surrounding plains forms ecological gradients and increases vegetative diversity through niche partitioning (Finke and Snyder 2008, Vivian-Smith 1997, Beatty 1984, Schoener 1974). Seasonality causes these landscape features to contribute to landscape heterogeneity and biological diversity differently throughout the year. As this landscape is a production landscape, managed and utilized by people, increase in agrodiversity at multiple scales follows (Brookfield and Padoch 1994). It leads to an increase in production system diversity. Additionally, it leads to an increase in rice germplasm diversity. A handful of flood-tolerant grass species, including wild rice *Oryza rufipogon*, grow in depressions on sites flooding to 3m or more. These *O. rufipogon* meadows may be a significant generator of rice varietal diversity as their proximity to deepwater rice fields facilitates gene flow between wild and domesticated *Oryza* populations (Niruntrayakul et al. 2009, Hajjar and Hodgkin, 2007).

Many livelihood activities take place on the open grasslands, wooded savannas and rice fields that dominate the landscape. However at some point in their performance, most of these activities are also associated with the *hillock-depression complex*. These complexes of hillocks and depressions pepper the floodplain landscape, and are important to floodplain residents today as they likely have been for centuries or even millenia (Stark 2006, Fox and Ledgerwood 1999). Despite their importance, hillock-depression complexes have yet to be described in detail.

Early observers of the floodplain landscape paid little attention to these formations, save cursory mentions or scattered observations of local residents or plant use (Zhou 2007, Groslier 2006, Thorel 2001, Mouhot 1864). There are no published ethnographies of

Tonle Sap floodplain communities, although Ebihara (1968) described her observations of a small agricultural village south of Phnom Penh. She discussed various systems of rice production and field layout, but she devoted little detail to the landscape surrounding the village and how it was managed. While not an ethnography *per se*, Delvert (1994 [1961]: 620-623) gives a very detailed discussion of floodplain land uses and livelihood in his compendium of Cambodian rural life. He also presented a case study which focuses specifically on the commune which contains the area of the present study. While he goes into some detail about farming systems, he does not explore how livelihood activities are situated in the landscape.

There have been a few recent treatments of floodplain livelihoods and land use around the Tonle Sap (Diepart 2008, Keskinen 2006, Sokha et al. 2006, Sokha et al. 2002). These recent studies differ both in scale and approach. Keskinen parsed up the entire Tonle Sap floodplain into a series of zones based on flood height, and characterized land uses and livelihoods associated with these zones based on surveys administered all around the Tonle Sap. Diepart, on the other hand, paired classification of digital orthophotos with village livelihood surveys to uncover patterns of land use and livelihood change in two communes in Kampong Thom Province. Sokha focused on land tenure, the change in the production of deepwater rice and the rise of dry season rice production in Kampong Thom Province. He did not explore the breadth of other resource management activities used on the floodplain.

Other authors have approached the floodplain from a conservation or wildlife management-based perspective (for snakes, Brooks et al. 2009, Brooks et al. 2008; and for birds, Gray et al. 2009, Gray et al. 2007, Davidson 2005). Additionally a growing archaeological literature describes the efforts to read the present day landscape for evidence of ancient settlement and land use patterns. Much of this work is focused on Angkor Wat in Siem Reap Province (Evans et al. 2007), or on Angkor Borei in Takeo Province on the Mekong floodplain (Stark 2007, Bishop et al. 2003). Archaeological sites on the floodplain in Kampong Thom have been cataloged in archeology surveys, but have yet to be explored in depth (Parmentier 1913 *inter alia*; for a site by site survey bibliography see CISARK 2010).

Recent Developments in Land Use

While floodplain land use is seldom stagnant, there are two recent trends in land use around the study site that are a growing concern. The first, rapid development of large-scale dry season rice production systems began several years ago, and is already impacting local land use. The second, petroleum exploration, started only recently and has yet to significantly affect land use by local residents.

Over the course of thirty years of war and civil unrest, much of the land on the floodplain in Kampong Thom Province owned by village residents was abandoned due to security concerns (Evans et al. 2005, Sokha et al. 2006). However, customary tenure over these locations was retained. Today, the security situation is much improved. Regardless, these lands are no longer planted to deepwater rice varieties as they once were. However, they remain important to village residents for commonly-managed fishing, livestock-keeping, grass collection and other extensive land use activities. Left uncultivated, these lands appear idle to official observers, as these activities are less legible than rice cultivation (Scott 1998). The appearance of abandonment has led to recent government encouragement of investors to develop those areas of the grassland considered vacant. Moreover, individual land owners in the village have been keen to cash in on their "unused" (i.e. uncultivated) parcels of floodplain land. As a result, much of the land more than a few kilometers from the village has been sold to private investors. Some of this land has yet to be developed, and is being held on speculation. Other areas have already been developed for dry season rice production.

Producing for the export market, these dry season rice farms are larger in scale than systems commonly used in nearby villages, with fields hundreds of hectares in size. They are more technologically intense than village systems, though there is variation between farms. Some agricultural tasks are still performed by hand, with hired laborers sowing seed and sometimes harvesting. Other activities, including plowing and threshing, are mechanized. Some wealthier farmers even hire combine harvesters, first seen in this area only a few years ago. Many farms, especially those farther from the dry season shore of the Tonle Sap itself, depend upon applications of synthetic fertilizers and pesticides. Producing during the dry season, these farms are also dependent upon large irrigation systems. Reservoirs, often dug in areas that were originally floodplain depressions, store floodwater for dry season use. Canals distribute the water to the fields in the charge area, while diesel powered pumps move water from the canals into the fields.

The number of these operations is not well known. Owners seldom register their activities with the provincial agricultural office. As a result, the only way that the expansion of this relatively new farming system has been tracked is through the use of remote sensing and field surveys by non-governmental organizations (NGOs). As of 2007, there were 20 reservoirs in Srayov Commune, Kampong Thom Province. This number will likely have grown by the time this reaches publication.

Dry season rice production systems reduce the ecological complexity of the floodplain by homogenizing what was once a mosaic of hillocks, depressions, grasslands and woodland into uniform reservoirs and rice fields. This results in a loss of habitat and changes in carbon flux, among other shifts in ecosystem services (Daily 1997, Chapin et al. 1997). Additionally, "improvement" of these areas leads to enclosure by the land owners, alienating village residents from land needed for grazing, collecting grasses and firewood as well as fishing. Moreover, many villagers recently surveyed described how the new rice farms block previously existing roads and substantially increase travel time through the area, making it more difficult to reach resource patches. The population of resource-users is growing annually while the area for resource management available to them is shrinking. Many households have access to non-local sources of income, such as factory work in Phnom Penh (Rigg 2006). However, even these sources of income are disappearing as factories close in response to changes in international trade (United Nations Country Team: Cambodia, 2009). The Tonle Sap floodplain is already the poorest region in Cambodia (Varis 2008). Should these trends continue, projections for the future of land-based livelihoods in the village appear grim. In early 2009, the Council of Ministers ordered a halt to further agricultural development until ecological impacts could be studied. However in the absence of adequate enforcement of the order, dry season rice expansion continues.

Oil exploration, on the other hand, has yet to directly impact the residents of the study site. Petroleum Geo-Services (PGS), in partnership with the Cambodian National Petroleum Authority (CNPA), began prospecting for oil on the floodplain of the Tonle Sap in Kampong Thom in 2007 (CNPA 2010). The results of these surveys have not been made public, although one NGO has reported that the block containing this area has already been promised to ATI Petroleum (Global Witness 2009). No information has been made available to detail how petroleum might be extracted should the surveys look promising, or how extraction might affect local residents. The Tonle Sap and its surrounding floodplain is the heart of Cambodia's fishery, producing an estimated 235 thousand tons annually (van Zalinge 2002). Some government officers reportedly are already willing to trade fishing productivity for oil profits. While future land use trajectories are difficult to predict, if petroleum extraction begins without incorporating local land use interests into the extraction plans, local residents will likely suffer.

Methodology

Data for this study were collected over the course of three periods of village-based research: May 2007-December 2007; March-June 2008 and January-May 2009. A range of methodologies were used; embracing an interdisciplinary approach integrating methods from the fields of geography, ecology and anthropology in order to explore land use and human ecology (Brookfield et al. 2002, Cunningham 2001, Scoones et al. 1994). These methods included semi-structured interviews with key informants (village elders and other local experts, but also including ministerial officers, local extension officers and employees of international development NGOs); field walks with key informants; unstructured interviews with village residents; written surveys focusing on land use (administered to 238 families, nearly 50% of the households in village) and participant-observation, joining village residents in their farming, fishing and livestock-keeping activities. A descriptive ecological inventory of floodplain vegetation was also performed (60 transects of 1000 m^2 each). Additionally, a time series of digital orthophotos was used to analyze land use/land cover change over time.

Research Site

The focal point of this research project was Roka Village (in Sangkat Srayov,[19] Steung Sen Municipality, Kampong Thom Province, at 12° 37' N 104° 55' E), a village of approximately 500 families on a finger of land jutting out from the edge of the Tonle Sap floodplain (Figure 1). The village lies between 10 m and 15 m asl, and gradually slopes down on 3 sides to meet the surrounding annually flooding rice fields and grasslands at approximately 10 m asl. It is connected to National Road 6, the paved road running between Phnom Penh and Siem Reap, by 4 km of improved dirt road.

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[19] The study area used to be under the administration of Srayov Commune, Steung Sen District, Kampong Thom Province. However, a new administrative naming system was introduced in late 2008. Borders remained unchanged.

The boundaries of the study area were selected based on preliminary interviews with Roka residents in order to incorporate as much of the land utilized by village residents as possible. As a result, study boundaries do not exactly follow administrative boundaries. Rather they more closely follow natural features. The northern boundary of the study area is the administrative border between Roka and Kamraeng Villages. To the east and south, the area is bounded by the Steung Slap (sometimes referred to as Steung Damrei Slap), a river flowing from north to south, eventually turning to the west. West of the village, the boundary follows the dirt road which runs from the village southwest. The boundary ultimately turns due south, passing to the west of Toul Kok Preah. The area forms a rough right triangle of approximately 122 km^2. The vast majority of the area lies within Sangkat Srayov, Steung Sen Municipality, Kampong Thom Province. However, a small portion in the southwest strays into Kampong Chhnang Province at Toul Kok Preah.

Some village residents travel beyond the borders delineated for this study to fish, tend livestock or collect fodder and firewood. However, such trips are not common. The daily activities of most village residents fall within the study boundaries.

The Hillock-Depression Complex

The hillock-depression complex is a landform on the floodplain landscape, or rather an association of landforms treated here as one landscape unit. The complex consists of one or more hillocks adjacent to one or more depressions. Both the hillock and depression components of the association vary in area, slope and elevation. They share common origins: alluvial, anthropogenic or a combination of the two. They also exhibit a diversity of settlement patterns, dominant vegetation, and land uses. In addition to being integral to the livelihoods of the people who live on and around the floodplain, they are centers of bio- and agrodiversity on the floodplain.

The local naming of these features supports the treatment of adjacent hillocks and depressions as a single complex. In Khmer, the landforms that constitute the hillock-depression complex have separate names. In most cases, the hillock component is referred to as ទួល (toul /tuəl/), translated variously as hillock, hill, knoll or mound (Headley et al. 1997, Headley 1977, Lewitz 1967). The depression component may be referred to by one of a handful of names for small water bodies, most commonly បឹង (boeng, /bəŋ/) or ត្រពាំង (trapeang, /trɑpeaŋ/). However, the local conception of these *places* also treats them as complexes of hillocks and depressions. During interviews, informants debated amongst themselves whether to refer to places by either lake or hillock, discussing the use of the name Grandfather Tia's Hillock versus Grandfather Tia's Pond, for example. They concluded that the terms were interchangeable. Either name might suffice as when one feature was found the other would not be far away. The name could be applied to either the hillock or the pond, as it applied not only to the landscape element but to the *place*. Additionally, depressions which are not associated with hillocks are also found within the study area. Depending upon their size, these may be referred to as either boeng (/bəŋ/, បឹង) or tlok (/tlok/, ថ្លុក), the former referring to larger, more permanent water bodies while the latter refers to smaller, seasonal ponds.[20]

Archaeological research in Cambodia has turned up evidence for the ancient construction of mounds which supported the construction of temples and houses (Penny et al. 2007). In addition to construction by humans, various other origins have been ascribed to floodplain hillocks including abiotic processes of floodplain geomorphology (de Fátima Rossetti et al. 2009), capture of sediment by termite mounds (McCarthy et al. 1998) and trees (Francis 2007, Gurnell and Petts 2006).

Both the construction of islands and the construction of hillocks on floodplains have been described from a few other parts of the world. Ivens (1930) described the construction of islands in lagoons among the Solomon Islands. Hillock construction and riparian landscape modification on the Amazonian *varzea* have been described from an archaeological perspective (de Fátima Rossetti et al.,2009, Roosevelt 1991). Raffles and WinklerPrins (2003), as well as Abizaid (2005), discussed present day landscape manipulation. Elsewhere in Latin America, Nordenskiöld (2009) described landscape modification techniques used on the flooding savannas of northeastern Bolivia. In a broad overview of soil manipulation and ethnopedology, WinklerPrins and Barrera-Bassols (2004) described soil manipulation techniques from throughout Latin America.

Though there have been several origins postulated in the literature for hillocks in other

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[20] The taxonomy of water bodies varies by locale, with some areas recognizing other categories of water body. In the study area, other terms are known by informants but seldom used to describe local landscape features.

parts of the world, the hillock-depression complexes on the Tonle Sap floodplain likely arose from one of two processes: anthropogenic landscape modification or alluvial processes. Additionally, there are hillock-depression complexes that appear to combine these two origins, where inhabitants of the floodplain modified existing hillocks of geomorphological origin, as has been suggested in Amazonia (de Fátima Rossetti et al. 2009).

Hillock-depression complexes of apparent anthropogenic origin are round, rectangular or irregularly shaped, sometimes with squared corners. They also are associated with one or more depressions that are often, though not always, rectangular in shape (Figure 14).

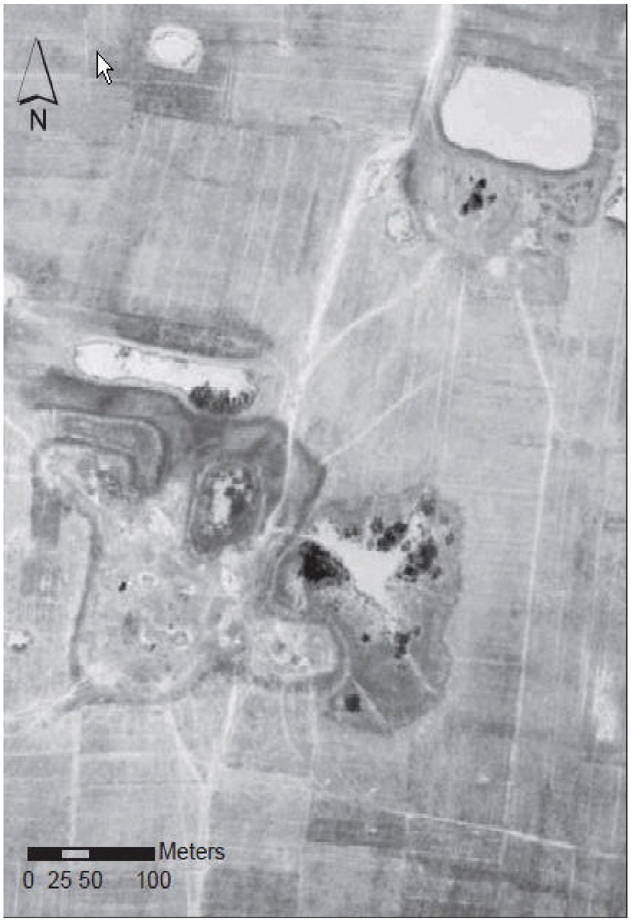

Figure 14. Examples of the hillock-depression complex of apparent anthropogenic origin. The two hillocks here are surrounded by rice fields, with adjacent ponds (depressions). In the upper right hand corner is Toul Kok Samroung, the hillock discussed in the case study, below. Orthophoto taken during the dry season of 2004 (imaged by Finnmap).

Despite the presence of many archaeological sites on the Tonle Sap floodplain, including several sites with stonework or ruins within the study area, the history of settlement of the floodplain remains poorly understood because the action of the annual flooding removes surface traces of occupation (D. Evans, pers. comm. 2009). Many hillocks within the study area appear to be of anthropogenic origin. But without excavation, it is possible only to speculate that they were constructed sometime before the French colonial occupation (1863-1953) (M. Stark, pers. comm. 2009). While this long history of use and habitation is acknowledged by local residents, they do not recognize hillocks as being of anthropogenic origin.

HDCs of apparent alluvial origin are elongated in shape and are found in proximity to an extant river, particularly near river bends. Appearing as meander scars on orthophotos, these hillocks and depressions likely are the remnants of levees and backswamps which were formed as rivers meandered across the floodplain.

HDCs Close to Roka Village

According to the manual classification of a 2005 dry season digital orthophoto using ArcView 9.2, there are 48 hillocks within the boundaries of the study area.[21] They range from 0.7 km to about 15 km from the village (median= 4.94 km, SD= 3.47 km). In area, they range from about 190 m^2 to 128000 m^2 (median= 9420.49 m^2, SD= 29312.22 m^2). The elevation of each hillock varies, generally ranging from 1-5 m above the surrounding plains, which range from 8-10 m asl, sloping gradually south towards the Tonle Sap lake.

Of the 179 toponyms collected during interviews with village residents, there were 132 landscape features classified as either a hillock or a pond within the study area. These represent 74% of all toponyms collected.

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[21] In this manual land use/land cover classification, hillocks and their associated depressions were classified separately. Thus the actual area of the hillock-depression *complexes*, the hillocks plus their associated depressions, is greater than the figure reported.

The difference between the number of collected names for HDCs and the number of hillocks recorded through the classification of the orthophoto is likely due to the informants' fine-grained discernment of landscape features that are not readily apparent in the orthophoto because of vegetational cover or subtle elevational changes.

HDCs and Floodplain Land Use

The dominant terrestrial landscape features on the floodplain are the broad, flat swaths of grassland and rice fields, or *veal* (វាល, /viel/). These areas are the site of some of the most visible, and economically important, land uses on the floodplain: rice production, livestock tending and fishing when the floodwaters cover the landscape. However, local residents also use other landscape features in their livelihood activities. Chief among them is the hillock-depression complex. Though these features may be seen as interstitial, squeezed in between savanna and rice field, they play a major role in a wide array of different livelihood activities. However, this diversity of land uses complicates land use classification and thus valuation of the landscape (Gallant 2009). While some activities are separated in space and time, many are not. They are neither mutually exclusive in terms of their location in the landscape nor in the time of their performance. Different people might perform different tasks at the same point in space, just as any single person might perform more than one task at the same time (Doolittle 2001). Moreover, the relative importance of any given land use changes throughout the year (and from year to year) as ecological and economic conditions dictate. Transitions between land use systems may be overlooked or misinterpreted (Padoch et al. 1998, Doolittle 1984). Lastly, these different activities also affect each other. Activities performed at one site shape how that location may be used later in the season and beyond (Foster et al. 2003). This flux complicates understanding the landscape without in-depth research, not always available to government decision-makers.

The hillock-depression complex was chosen as an example of one landscape feature common on the floodplain to illustrate the role of landscape diversity in floodplain livelihoods, and how sometimes these are important in small-scale land use, both legible and illegible. HDCs figure prominently in many floodplain-based livelihood activities. Some of these are readily apparent from the air or ground (e.g. cultivation). Many other activities are illegible to outsiders, either because they are difficult to discern visually or they are not major contributors to the national economy. For these reasons, HDCs are an example of a landscape feature that is particularly important to understand when evaluating opportunities for further natural resource development on the floodplain. A sampling of land uses that occur on or around HDCs is found in Table 12.

A typology serves as a framework to categorize land uses, but it does not illustrate how these uses fit together in a spatio-temporal context. For this, it is necessary to use place-based narrative case studies that focus on specific sites on the floodplain, and describe how uses overlap each other at the same point in space, or shift from one to the next as time passes (Lambin et al. 2003). What follows is a case study from the research site.

Table 12. Livelihood and cultural activities observed to be associated with hillock-depression complexes.

Land Use or Activity	Observations
Plant resource extraction	Year-round. Dry season fruits, firewood, cordage and medicinal plants. Wet season edible water lilies, reeds for weaving mats, fodder (*Oryza rufipogon* L.), water hyacinth from depressions.
Fishing	Year-round. Dry season in water-filled depressions. Wet season over the entire water-covered landscape. Dry season: collection of other aquatic animals, such as frogs and crabs.
Agricultural production	Year-round. Vegetables, fruits and *Borassus* palm from hillocks, adjacent depressions source of irrigation water. Some depressions with deepwater rice, lotus during the wet season.
Soil and manure collection	Dry season. Soil collected for field leveling, road building and other engineering purposes. Manure-rich soil from stock corrals collected to be used as a field amendment.
Livestock shelter	Year-round. Wet season: water buffalo. Dry season: cattle. Stock may be kept in a corral atop the hillock, watering at the adjacent pond. Free-ranging stock also spontaneously seek shelter on the wooded hillocks to avoid noontime heat.
Staging	Year-round. Hillocks are often used as sites to prepare for and recover from activities that are performed on the fields surrounding them, such as rice farming and roofing thatch collection.
Settlement	Year-round/seasonal. Some HDCs are the sites of permanent settlements. Other settlements are temporary, being inhabited only for one season or even a just few months.
Hiding	Intermittent. During times of civil unrest, village residents and outlaws alike take shelter on these sites to avoid detection.
Ritual	Intermittent. Some hillocks are used for the performance of rituals. Some rituals are performed annually to honor the spirits which inhabit these sites. Others are performed as needed to request spiritual intercession for assistance with problems. Ritual sites are often associated with *Ficus religiosa*.
Reference	Year-round. Hillocks are among the most visible landscape features on the floodplain. All within the study area were named. As such they serve as reference points for land navigation, as well as for the relaying of information about the landscape.
Rest	Dry Season. Wagon caravans on long overland voyages to fish at Tonle Sap shore make temporary camps at HDCs. Year-round along rivers. HDCs along rivers are also used as landings and campsites by travelers and fishers.

HDC Land Use Case Study: Toul Kok Samroung[22]

Toul Kok Samoung is a small, sparsely wooded hillock about 3km south of Roka Village along one of the two unimproved sand roads which lead south out onto the floodplain (Figure 14, upper right-hand corner of the image). It is surrounded by rice fields which are typically used to plant modern rice varieties maturing in 3 months time. When the floodwaters rise, these fields are not flooded deeply, usually less than 0.5 m. There are several *Tamarindus indica* and *Zizyphus mauritiana* trees atop of the otherwise grass-covered hill. The shade provided by the trees atop the hillock make this site very desirable. Nearby hillocks have already been cleared of woody vegetation, reportedly cut for firewood. Adjacent to the hill is a small pond that in 2009 had been cleared of aquatic and border vegetation.

During the growing season (from approximately May to December), the hill is used by the owners of the surrounding rice fields as a staging area, camping during planting and harvesting. This saves them time during the commute to and from the village. However land use during the dry season is more elaborate.

As the annual floods recede, grasses regenerate on the stubble-covered fields that surround the hillock, as with elsewhere on the floodplain. This early flush of growth is important for cattle and buffalo coming out of the flood period, when fodder is scarce. At this time, people who live in the villages around the floodplain graze their livestock on

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[22] ទួលគោកសំរោង , /tuəl kook sɑmraoŋ/.

these spontaneous pastures. Not every family can spare the labor to send someone, usually a male child, teenager or an old man, to supervise the herd. As a result, some individuals or families establish themselves as herders-for-hire on the floodplain. Such arrangements center around HDCs, as the hillocks provide a site for sheltering both stock and herder alike, while adjacent depressions are a source of water.

At Kok Samroung, as with other HDCs used by dry season herders, not long after the floods recede the hillock is claimed by the family who will use it for the dry season. The first to arrive at the hillock has claim to use it, regardless of whether or not they had stayed at the hillock in previous years. Once the site is secured, a raised shelter and corral are built. Cattle are then tended until just before Khmer New Year (early-mid April), when the stock owners return to collect their animals. The couple staying at that site in 2009 were responsible for approximately 80 head of cattle. The cattle graze freely on the surrounding grasslands, returning to the corral at night. The pond is used as a source of water for both drinking and bathing. For this effort, the couple would be paid a flat 25,000 riel (about US$6.25) per animal. They also sold manure from the livestock enclosure, used as a soil amendment elsewhere. With the arrival of New Year and the surrender of their charges, the hillock is vacated until the planting season begins again.

While cattle herding is the dominant dry season land use, there are other activities evident at the site. Among them, duck tending and fish bait collection. Additionally, the fruits of both the *Tamarindus* and *Zizyphus* were collected by residents of the hillock and as well as passers-by for eating out of hand or in prepared dishes.

Conclusion

The landscape of the Tonle Sap floodplain is diverse: biologically, agriculturally and topographically. It is also changing rapidly under current land use schemes. Despite the apparent abandonment of the flooding savannas surrounding Roka Village, the landscape remains important to village residents for the wide array of livelihood activities that are performed there. While some of these activities are readily apparent from the ground or from aerial photography, others are more subtle which renders the landscape illegible to outside observers. This illegibility has practical implications when the importance of the landscape to local residents is neglected by decision-makers. As the floodplain is developed for agricultural production, petroleum extraction and other activities, it is necessary to take a broad view of land use when weighing the potential effects of land use changes on the lives of local residents. Appreciating those livelihood activities that have subtle land use footprints has the potential to lead to a more equitable outcome in planning grassland natural resource management (Dove 2008). In the case of Roka Village, unrestricted dry season rice production has already complicated herding, fishing and gathering activities for village residents. If current trends in agricultural expansion, population growth and international trade continue, this trend will only worsen. Petroleum exploration remains at an early stage. Should the government and partnering private companies choose to proceed, it is still possible for equity to be incorporated into the projects so that the natural resource-based livelihood activities that have sustained floodplain households for millenia are not lost.

Chapter 6

Conclusion: Flexibility in Complexity

"The only thing we are able to do is struggle and persist."
– a farmer, Roka Village.

The Tonle Sap landscape is dynamic: driven by cycles and stochasticity, characterized by variability. This presents a suite of challenges for those who make their lives on the floodplain. The same holds true for floodplain flora and fauna. All need the ability to take advantage of windows of opportunity while at the same time avoiding windows of vulnerability (Wantzen et al 2008). The preceding chapters each focused on different facets of the relationships between village residents, the surrounding landscape and the plant communities which populate it. Chapter 2 explored the history of the landscape around Roka Village. It presented an analysis of land use/land cover change over time, and of LULC change trajectories based on LULC maps prepared from a time-series of aerial photographs. Based upon changes in the spatial pattern of change in LULC classes, the landscape was determined to be simplifying: becoming more homogeneous as the area under each LULC class becomes more evenly distributed amongst the classes. Two broad trends in LULC change were identified: the effects of agricultural expansion due to increasing population pressure, and the increase in shrubland cover due to Cambodia's long civil war. Finally, a case study highlighted the intersection of multiple biophysical and social process with individual agency by situating the emergence of small scale, flood recession rice production within the broader fabric of landscape history. The land use/land cover classification scheme introduced in this chapter served as the organizing principle for the following 3 chapters.

Chapter 3 focused on the phytosociology of floodplain plant communities as derived from a descriptive ecological inventory. Dominant species for each LULC class were presented, community structure was derived from dominance-diversity curves and a relevé table, and the population structures of two important tree species were analyzed. The interaction of present day land use, historical land use and biophysical processes was highlighted as the central factor guiding vegetation dynamics, and importantly a generator of landscape diversity.

Chapter 4 presented the results of a land use survey in which village residents free-listed livelihood activities which they engaged in for each LULC class. Based upon these data, the number of livelihoods in which a household engages is correlated to the number of LULC classes which they utilize; households with diverse livelihood portfolios utilize a diverse landscape. Moreover, floodplain livelihoods are partitioned in space by the structure of the landscape. Many livelihood activities also exhibit a distinct seasonality and are thus partitioned in time. However, households confront a variety of challenges in natural resource utilization. Major categories of challenge were presented. These illustrate some of the long-term trends which are perceived to have a negative effect on livelihood portfolios. These trends included increases in village population, increasing numbers of resource harvesters (both local and migrant), and also the enclosure and development of floodplain land by private, large-scale farmers. Despite these trends, spatio-temporal partitioning of livelihood activities and the utilization of a diverse landscape remain crucial to floodplain households, as they are a source of flexibility necessary to both weather shocks and grasp new opportunities.

Chapter 5 presented a case study of a newly-described landscape element, termed here the Hillock-Depression Complex. The Hillock-Depression Complex figures prominently in many different livelihood activities throughout the year. A substantial proportion of these activities leave a scant visual signature and remain illegible to outsiders. Illegibility to policy-makers has led to land use policies which undervalue the landscape and are alienating local residents from the natural resources associated with HDCs, upon which they have depended upon in the past. Building on the challenging trends presented in Chapter 4, this case study illustrates the negative effects of landscape simplification and unfettered agricultural development as households lose access to the resources upon which their flexibility depends, leaving them more vulnerable to negative ecological, economic or political changes.

Dynamics and Scale

Each of these treatments characterized dynamics active in a different domain: landscape structure as it relates to historical processes and individual agency (Chapter 2), plant community composition as it relates to land use (Chapter 3), household livelihood portfolios as they relate to time and space (Chapter 4), and land use as it relates to place, power and policy (Chapter 5). Each of the dynamics described corresponds to processes operating at different scales. These scales are not simply different levels within a single, nested hierarchy. Rather these chapters describe processes and effects from different hierarchical levels of different *kinds* of scale: observational, operational, social, and spatio-temporal (McMaster and Shepard 2004).

This diversity of scales poses methodological challenges. To focus on one scale is to study but a portion of the system (Parker and Pickett 1998). Issues of scale are further confounded through "scaling parsimony" (Turner 1999), whether applied knowingly or not, in which it is presumed *a priori* that dynamics are most immediately affected by processes which operate at the same scale as the observed changes. Such is not always the case.

Turner's definition of scaling parsimony could further be expanded to include not only processes driving dynamics, but also the dynamics themselves. The dynamics of landscape change in this study are an example of the complexity of dynamics at different scales. In one relatively coarse-grained analysis, using landscape ecological descriptors and digital orthophotos of the entire study area, the landscape was seen to be simplifying, with LULC classes becoming more evenly distributed over the landscape. However relatively fine-grained, field-based data collection and analysis techniques illuminate the landscape from another angle, concluding that the the livelihood activities of floodplain households generate landscape diversity. The analytical techniques used here focus on different scales and illustrate landscape dynamics differently, suggesting that the *a priori* application of the “village scale” may not have been appropriate for disentangling these complex dynamics.[23] Though it did reveal these scalar relationships and thus suggests avenues for further research.

The multi-scalar approach used in this study was taken in order to maintain a broad field

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[23] For a detailed discussion of scale in ecology, particularly the “landscape scale” and “landscape level”, see Allen 1998.

of vision, engaging with multiple processes which shape plant-people-landscape relationships on the floodplain (Reenberg and Fog 1995). While not claiming to have been an inventory of scalar relationships, the results of this study do hint at the diversity of scales and cross-scalar linkages at work in landscape-livelihood dynamics.

Co-Production of Landscapes and Livelihoods

The floodplain landscape has been inhabited for centuries, perhaps millenia, not *in spite of* this complexity but rather *because of* its tremendous complexity. Though extremes are difficult to weather, year-to-year the environment is very productive. Individual floodplain residents have many strategies to manage this productivity. Important among them is the maintenance of complex portfolios of natural resource-based livelihood activities. While a few livelihood activities are dominant (rice farming, livestock keeping, fishing), households engage in many different activities for both subsistence and market-oriented activities. The organization of livelihood portfolios is always changing in response to new opportunities and challenges. Moreover, the ability to spread out livelihood activities in space and time takes advantage of the patchy distribution of different plant communities, as well as the seasonal flux in plant community composition and structure.

While management for landscape diversity may not be an explicit goal of natural resource-based livelihood activities on the floodplain, it has been an outcome. People on the floodplain are not passive subjects, solely acted upon by outside processes. Indeed they are actice agents in generating diversity. Human activities shape plant communities, whether by burning, cutting, leveling, clearing, grazing, planting or abandoning. Historical contingency is a critical element. Land use history, and cycles of agricultural expansion and contraction allow patches of varying ages and management histories to regenerate differently, contributing to the landscape mosaic (Parker and Pickett 1998).

In a material sense, landscapes and natural resource-based livelihoods are products of one another and are physical manifestations of the interactions of village residents with a diversity of processes, both biophysical and social.[24] In the case presented here, landscape complexity has made diverse natural resource-based livelihoods possible. Livelihood diversity is a source of household flexibility, a dynamic continuity in the face of near constant change. In managing plant communities for diverse livelihoods, landscape complexity is maintained. Thus one is a product of the other. People are not separate agents acting *on* the landscape, but they are agents acting *in* the landscape, at once producers of and products of, the landscape.

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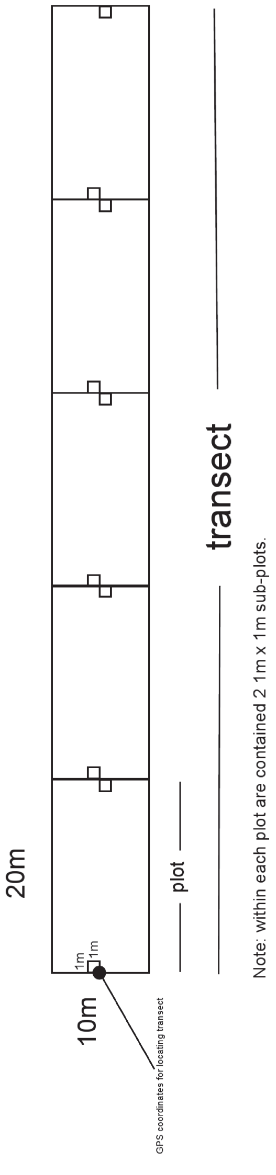
[24] McCusker and Carr (2006) distill the co-productive relationship further, focusing specifically on power relationships as the crystallization point between social processes, land use change and livelihoods.

Appendix 1: Transect Schematic

Appendix 1: Transect Schematic



Note: within each plot are contained 2 1m x 1m sub-plots.

Appendix 2: Inventory Transect Locations

Appendix 2: Inventory Transect Locations

Randomly Generated Primary Locations and Back-Up Locations

Primary inventory locations for each land use/land cover class are shaded.

Site Number	Latitude	Longitude	LULC Class
f1	12.55	104.91	Shrubland
f2	12.61	104.94	Shrubland
f3	12.61	104.92	Shrubland
f4	12.53	104.89	Shrubland
f5	12.56	104.91	Shrubland
f6	12.53	104.9	Shrubland
f7	12.53	104.88	Shrubland
f8	12.55	104.91	Shrubland
f9	12.53	104.89	Shrubland
f10	12.55	104.91	Shrubland
f11	12.54	104.93	Shrubland
f12	12.61	104.94	Shrubland
f13	12.54	104.85	Shrubland
f14	12.54	104.82	Shrubland
f15	12.54	104.85	Shrubland
f16	12.59	104.92	Shrubland
f17	12.55	104.92	Shrubland
f18	12.54	104.87	Shrubland
f19	12.53	104.85	Shrubland
f20	12.56	104.93	Shrubland
f21	12.53	104.82	Shrubland
f22	12.58	104.94	Shrubland
f23	12.55	104.92	Shrubland
f24	12.55	104.92	Shrubland
f25	12.61	104.94	Shrubland
f26	12.58	104.94	Shrubland
f27	12.61	104.91	Shrubland
f28	12.57	104.94	Shrubland
f29	12.57	104.93	Shrubland
f30	12.53	104.89	Shrubland
f31	12.54	104.94	Shrubland
f32	12.53	104.9	Shrubland
f33	12.54	104.94	Shrubland
f34	12.53	104.88	Shrubland
f35	12.58	104.93	Shrubland
f36	12.55	104.9	Shrubland

Site Number	Latitude	Longitude	LULC Class
f37	12.53	104.85	Shrubland
f38	12.57	104.94	Shrubland
f39	12.54	104.87	Shrubland
f40	12.54	104.89	Shrubland
g1	12.53	104.91	Grassland
g2	12.55	104.85	Grassland
g3	12.57	104.86	Grassland
g4	12.56	104.85	Grassland
g5	12.56	104.83	Grassland
g6	12.54	104.88	Grassland
g7	12.57	104.87	Grassland
g8	12.54	104.9	Grassland
g9	12.53	104.9	Grassland
g10	12.57	104.86	Grassland
g11	12.58	104.87	Grassland
g12	12.54	104.92	Grassland
g13	12.55	104.82	Grassland
g14	12.54	104.88	Grassland
g15	12.57	104.87	Grassland
g16	12.6	104.88	Grassland
g17	12.57	104.86	Grassland
g18	12.54	104.83	Grassland
g19	12.54	104.91	Grassland
g20	12.54	104.86	Grassland
g21	12.57	104.88	Grassland
g22	12.59	104.88	Grassland
g23	12.54	104.85	Grassland
g24	12.58	104.88	Grassland
g25	12.55	104.86	Grassland
g26	12.55	104.88	Grassland
g27	12.55	104.9	Grassland
g28	12.55	104.91	Grassland
g29	12.54	104.82	Grassland
g30	12.57	104.87	Grassland
g31	12.53	104.81	Grassland
g32	12.54	104.83	Grassland
g33	12.59	104.86	Grassland
g34	12.56	104.83	Grassland
g35	12.58	104.86	Grassland
g36	12.6	104.87	Grassland
g37	12.58	104.86	Grassland
g38	12.55	104.85	Grassland
g39	12.54	104.9	Grassland

Site Number	Latitude	Longitude	LULC Class
g40	12.53	104.81	Grassland
g41	12.55	104.84	Grassland
g42	12.54	104.82	Grassland
g43	12.52	104.88	Grassland
g44	12.57	104.88	Grassland
g45	12.55	104.85	Grassland
g46	12.54	104.83	Grassland
g47	12.56	104.87	Grassland
g48	12.57	104.87	Grassland
g49	12.57	104.86	Grassland
g50	12.56	104.83	Grassland
h1	12.6	104.91	Hillock
h2	12.57	104.92	Hillock
h3	12.59	104.93	Hillock
h4	12.59	104.9	Hillock
h5	12.53	104.82	Hillock
h6	12.59	104.9	Hillock
h7	12.56	104.93	Hillock
h8	12.56	104.93	Hillock
h9	12.6	104.91	Hillock
h10	12.57	104.92	Hillock
h11	12.6	104.91	Hillock
h12	12.58	104.95	Hillock
h13	12.59	104.92	Hillock
h14	12.59	104.92	Hillock
h15	12.61	104.92	Hillock
h16	12.53	104.86	Hillock
h17	12.6	104.95	Hillock
h18	12.53	104.82	Hillock
h19	12.53	104.82	Hillock
h20	12.6	104.93	Hillock
h21	12.6	104.93	Hillock
h22	12.6	104.91	Hillock
h23	12.59	104.93	Hillock
h24	12.6	104.95	Hillock
h25	12.58	104.95	Hillock
h26	12.53	104.82	Hillock
h27	12.6	104.94	Hillock
h28	12.6	104.91	Hillock
h29	12.6	104.95	Hillock
h30	12.62	104.93	Hillock
h31	12.61	104.92	Hillock
h32	12.6	104.91	Hillock

Site Number	Latitude	Longitude	LULC Class
h33	12.61	104.91	Hillock
h34	12.6	104.93	Hillock
h35	12.6	104.91	Hillock
h36	12.59	104.93	Hillock
h37	12.59	104.9	Hillock
h38	12.53	104.86	Hillock
h39	12.6	104.95	Hillock
h40	12.6	104.91	Hillock
r1	12.61	104.91	Ricefield
r2	12.61	104.91	Ricefield
r3	12.6	104.93	Ricefield
r4	12.61	104.88	Ricefield
r5	12.56	104.93	Ricefield
r6	12.6	104.92	Ricefield
r7	12.58	104.88	Ricefield
r8	12.56	104.93	Ricefield
r9	12.56	104.93	Ricefield
r10	12.62	104.89	Ricefield
r11	12.61	104.89	Ricefield
r12	12.62	104.91	Ricefield
r13	12.58	104.94	Ricefield
r14	12.6	104.93	Ricefield
r15	12.57	104.9	Ricefield
r16	12.61	104.93	Ricefield
r17	12.61	104.93	Ricefield
r18	12.59	104.91	Ricefield
r19	12.59	104.93	Ricefield
r20	12.61	104.91	Ricefield
r21	12.58	104.94	Ricefield
r22	12.62	104.89	Ricefield
r23	12.62	104.92	Ricefield
r24	12.56	104.89	Ricefield
r25	12.59	104.94	Ricefield
r26	12.58	104.9	Ricefield
r27	12.58	104.91	Ricefield
r28	12.6	104.93	Ricefield
r29	12.58	104.92	Ricefield
r30	12.62	104.89	Ricefield
r31	12.56	104.9	Ricefield
r32	12.63	104.92	Ricefield
r33	12.58	104.89	Ricefield
r34	12.62	104.94	Ricefield
r35	12.61	104.89	Ricefield

Site Number	Latitude	Longitude	LULC Class
r36	12.61	104.94	Ricefield
r37	12.61	104.91	Ricefield
r38	12.56	104.93	Ricefield
r39	12.55	104.93	Ricefield
r40	12.59	104.92	Ricefield
r41	12.6	104.95	Ricefield
r42	12.58	104.92	Ricefield
r43	12.58	104.88	Ricefield
r44	12.58	104.91	Ricefield
r45	12.57	104.9	Ricefield
r46	12.58	104.89	Ricefield
r47	12.59	104.89	Ricefield
r48	12.62	104.92	Ricefield
r49	12.62	104.9	Ricefield
r50	12.57	104.88	Ricefield

Appendix 3a-d: Importance Value Calculations

Woody Species by Land Use/Land Cover Class

Appendix 3a: Importance Value Calculations, LULC Class Shrubland

Species	Density/Ha	Relative Density	Basal Area	Relative Basal Area	Frequency	Relative Frequency	Importance Value
Acacia thailandica	6.25000	0.00098	0.00094	0.00039	1.00000	0.00730	0.28918
Aeschynomene aspera	4.16667	0.00066	0.00126	0.00052	2.00000	0.01460	0.52593
Albizia saman	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Annona sp.	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Antidesma cochinchinensis	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Antidesma ghaesembilla	11.45833	0.00180	0.00929	0.00387	5.00000	0.03650	1.40568
aw krawpeuh	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
bai krium	12.50000	0.00197	0.00165	0.00069	2.00000	0.01460	0.57508
banlah dei suhut	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Barringtonia acutangula	231.25000	0.03638	0.53085	0.22130	12.00000	0.08759	11.50877
Bombax ceiba	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Borassus flabellifer	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Breynia sp.	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Bridelia ovata subsp. curtisii	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Capparis sp.	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Carica papaya	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Cayratia carnosa	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Ceiba pentandra	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
chleuy	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
chomtooal bong moan	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Chromolaena odorata	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
chuung buah	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Combretum trifoliatum	34.37500	0.00541	0.00330	0.00138	2.00000	0.01460	0.71269
Crateva adansonii subsp. odora	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Cratoxylum cochinchinense	8.33333	0.00131	0.02144	0.00894	4.00000	0.02920	1.31487
Croton sp.	951.04167	0.14960	0.17145	0.07147	14.00000	0.10219	10.77540
Croton sp.	1.04167	0.00016	0.00049	0.00020	1.00000	0.00730	0.25559
daum bat leuh	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Dendrolobium sp.	83.33333	0.01311	0.00805	0.00336	5.00000	0.03650	1.76535
dombai	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Dysoxylum procerum	97.91667	0.01540	0.01869	0.00779	8.00000	0.05839	2.71963
Eriobotrya bengalensis	3.12500	0.00049	0.00106	0.00044	1.00000	0.00730	0.27443
Feroniella lucida	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Gmelina asiatica	3895.83333	0.61281	1.44641	0.60297	45.00000	0.32847	51.47490
Hymenocardia wallichii	310.41667	0.04883	0.07076	0.02950	10.00000	0.07299	5.04403
Jatropha curcas	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
kasoouah	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
kawtooul	1.04167	0.00016	0.00196	0.00082	1.00000	0.00730	0.27605
kbah prei	13.54167	0.00213	0.00573	0.00239	2.00000	0.01460	0.63729
kbuht	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
knai moan	3.12500	0.00049	0.00259	0.00108	1.00000	0.00730	0.29571
kompleang	4.16667	0.00066	0.00141	0.00059	1.00000	0.00730	0.28480
mreah preu	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
nyeeah	2.08333	0.00033	0.00393	0.00164	1.00000	0.00730	0.30880
nyo	15.62500	0.00246	0.00118	0.00049	4.00000	0.02920	1.07153
Peltophorum	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Pithecellobium dulce	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Sesbania javanica	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Solanum sp.	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Solanum torvum	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Stephegyne parvifolia	6.25000	0.00098	0.00259	0.00108	1.00000	0.00730	0.31209
Streblus asper	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
swai kteeh	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Tamarindus indica	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Terminalia cambodiana	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
tlaum andauk	368.75000	0.05800	0.02780	0.01159	10.00000	0.07299	4.75291
Vitex holoadenon	291.66667	0.04588	0.06597	0.02750	4.00000	0.02920	3.41929
voah preng	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Zizyphus mauritiana	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Zizyphus oenoplia	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

Appendix 3b: Importance Value Calculations, LULC Class Grassland

Species	Density/Ha	Relative Density	Basal Area	Relative Basal Area	Frequency	Relative Frequency	Importance Value
Acacia thailandica	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Aeschynomene aspera	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Albizia saman	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Annona sp.	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Antidesma cochinchinensis	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Antidesma ghaesembilla	9.18367	0.00323	0.02490	0.00905	5.00000	0.03106	1.44470
aw krawpeuh	1.02041	0.00036	0.00016	0.00006	1.00000	0.00621	0.22092
bai krium	53.06122	0.01868	0.01846	0.00671	8.00000	0.04969	2.50261
banlah dei suhut	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Barringtonia acutangula	83.16327	0.02927	1.02330	0.37207	12.00000	0.07453	15.86248
Bombax ceiba	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Borassus flabellifer	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Breynia sp.	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Bridelia ovata subsp. curtisii	8.67347	0.00305	0.00385	0.00140	4.00000	0.02484	0.97657
Capparis sp.	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Carica papaya	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Cayratia carnosa	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Ceiba pentandra	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
chleuy	1.02041	0.00036	0.00141	0.00051	1.00000	0.00621	0.23615
chomtooal bong moan	31.12245	0.01096	0.00838	0.00305	3.00000	0.01863	1.08791
Chromolaena odorata	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
chuung buah	1.02041	0.00036	0.00063	0.00023	1.00000	0.00621	0.22663
Combretum trifoliatum	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Crateva adansonii subsp. odora	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Cratoxylum cochinchinense	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Croton sp.	361.22449	0.12716	0.13218	0.04806	13.00000	0.08075	8.53205
Croton sp.	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
daum bat leuh	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Dendrolobium sp.	24.48980	0.00862	0.00518	0.00188	4.00000	0.02484	1.17834
dombai	2.55102	0.00090	0.00073	0.00026	1.00000	0.00621	0.24578
Dysoxylum procerum	112.24490	0.03951	0.07946	0.02889	10.00000	0.06211	4.35052
Eriobotrya bengalensis	4.08163	0.00144	0.00424	0.00154	1.00000	0.00621	0.30633
Feroniella lucida	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Gmelina asiatica	1609.18367	0.56645	0.79628	0.28952	46.00000	0.28571	38.05627
Hymenocardia wallichii	340.81633	0.11997	0.25044	0.09106	24.00000	0.14907	12.00333
Jatropha curcas	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
kasoouah	5.10204	0.00180	0.00079	0.00029	1.00000	0.00621	0.27642
kawtooul	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
kbah prei	0.51020	0.00018	0.00385	0.00140	1.00000	0.00621	0.25967
kbuht	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
knai moan	3.06122	0.00108	0.01720	0.00625	2.00000	0.01242	0.65846
kompleang	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
mreah preu	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
nyeeah	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
nyo	42.34694	0.01491	0.00864	0.00314	2.00000	0.01242	1.01567
Peltophorum	1.02041	0.00036	0.00016	0.00006	1.00000	0.00621	0.22092
Pithecellobium dulce	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Sesbania javanica	60.71429	0.02137	0.09753	0.03546	3.00000	0.01863	2.51553
Solanum sp.	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Solanum torvum	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Stephegyne parvifolia	15.30612	0.00539	0.18891	0.06869	8.00000	0.04969	4.12545
Streblus asper	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
swai kteeh	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Tamarindus indica	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Terminalia cambodiana	0.51020	0.00018	0.07069	0.02570	1.00000	0.00621	1.06973
tlaum andauk	69.38776	0.02443	0.01296	0.00471	8.00000	0.04969	2.62755
Vitex holoadenon	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
voah preng	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Zizyphus mauritiana	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Zizyphus oenoplia	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

Appendix 3c: Importance Value Calculations, LULC Class Hillock

Species	Density/Ha	Relative Density	Basal Area	Relative Basal Area	Frequency	Relative Frequency	Importance Value
Acacia thailandica	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Aeschynomene aspera	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Albizia saman	4.00000	0.00157	0.42938	0.07872	2.00000	0.01266	3.09839
Annona sp.	2.00000	0.00079	0.00063	0.00012	1.00000	0.00633	0.24104
Antidesma cochinchinensis	8.00000	0.00315	0.00817	0.00150	1.00000	0.00633	0.36579
Antidesma ghaesembilla	12.00000	0.00472	0.06933	0.01271	7.00000	0.04430	2.05781
aw krawpeuh	2.00000	0.00079	0.04438	0.00814	2.00000	0.01266	0.71935
bai krium	6.00000	0.00236	0.00047	0.00009	1.00000	0.00633	0.29253
banlah dei suhut	4.00000	0.00157	0.00055	0.00010	1.00000	0.00633	0.26678
Barringtonia acutangula	104.00000	0.04091	0.22938	0.04205	10.00000	0.06329	4.87522
Bombax ceiba	41.00000	0.01613	0.02741	0.00503	5.00000	0.03165	1.76000
Borassus flabellifer	2.00000	0.00079	0.28873	0.05293	1.00000	0.00633	2.00168
Breynia sp.	10.00000	0.00393	0.00267	0.00049	3.00000	0.01899	0.78036
Bridelia ovata subsp. curtisii	48.00000	0.01888	0.03144	0.00576	6.00000	0.03797	2.08741
Capparis sp.	4.00000	0.00157	0.07155	0.01312	1.00000	0.00633	0.70067
Carica papaya	9.00000	0.00354	0.04398	0.00806	2.00000	0.01266	0.80874
Cayratia carnosa	35.00000	0.01377	0.02231	0.00409	3.00000	0.01899	1.22818
Ceiba pentandra	6.00000	0.00236	0.33859	0.06207	2.00000	0.01266	2.56977
chleuy	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
chomtooal bong moan	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Chromolaena odorata	323.00000	0.12707	0.03230	0.00592	9.00000	0.05696	6.33163
chuung buah	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Combretum trifoliatum	2.00000	0.00079	0.00141	0.00026	1.00000	0.00633	0.24584
Crateva adansonii subsp. odora	6.00000	0.00236	0.01885	0.00346	5.00000	0.03165	1.24872
Cratoxylum cochinchinense	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Croton sp.	455.00000	0.17899	0.13862	0.02541	10.00000	0.06329	8.92327
Croton sp.	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
daum bat leuh	4.00000	0.00157	0.00031	0.00006	1.00000	0.00633	0.26534
Dendrolobium sp.	69.00000	0.02714	0.01769	0.00324	5.00000	0.03165	2.06776
dombai	1.00000	0.00039	0.00008	0.00001	1.00000	0.00633	0.22456
Dysoxylum procerum	13.00000	0.00511	0.23952	0.04391	5.00000	0.03165	2.68908
Eriobotrya bengalensis	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Feroniella lucida	38.00000	0.01495	0.69443	0.12731	3.00000	0.01899	5.37498
Gmelina asiatica	493.00000	0.19394	0.19895	0.03648	13.00000	0.08228	10.42318
Hymenocardia wallichii	204.00000	0.08025	0.11632	0.02133	6.00000	0.03797	4.65172
Jatropha curcas	489.00000	0.19237	0.22855	0.04190	5.00000	0.03165	8.86384
kasoouah	8.00000	0.00315	0.00287	0.00053	2.00000	0.01266	0.54436
kawtooul	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
kbah prei	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
kbuht	1.00000	0.00039	0.00503	0.00092	1.00000	0.00633	0.25480
knai moan	1.00000	0.00039	0.00785	0.00144	1.00000	0.00633	0.27208
kompleang	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
mreah preu	1.00000	0.00039	0.00008	0.00001	1.00000	0.00633	0.22456
nyeeah	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
nyo	4.00000	0.00157	0.00031	0.00006	1.00000	0.00633	0.26534
Peltophorum	18.00000	0.00708	0.85216	0.15623	7.00000	0.04430	6.92050
Pithecellobium dulce	9.00000	0.00354	0.11971	0.02195	5.00000	0.03165	1.90446
Sesbania javanica	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Solanum sp.	7.00000	0.00275	0.00124	0.00023	1.00000	0.00633	0.31032
Solanum torvum	3.00000	0.00118	0.00691	0.00127	1.00000	0.00633	0.29255
Stephegyne parvifolia	14.00000	0.00551	0.42005	0.07701	4.00000	0.02532	3.59446
Streblus asper	7.00000	0.00275	0.08184	0.01500	1.00000	0.00633	0.80289
swai kteeh	1.00000	0.00039	0.00031	0.00006	1.00000	0.00633	0.22600
Tamarindus indica	2.00000	0.00079	0.00167	0.00031	1.00000	0.00633	0.24740
Terminalia cambodiana	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
tlaum andauk	2.00000	0.00079	0.00016	0.00003	1.00000	0.00633	0.23816
Vitex holoadenon	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
voah preng	1.00000	0.00039	0.00008	0.00001	1.00000	0.00633	0.22456
Zizyphus mauritiana	40.00000	0.01574	0.63087	0.11566	11.00000	0.06962	6.70055
Zizyphus oenoplia	29.00000	0.01141	0.02737	0.00502	6.00000	0.03797	1.81337

Appendix 3d: Importance Value Calculations, LULC Class Ricefield

Species	Density/Ha	Relative Density	Basal Area	Relative Basal Area	Frequency	Relative Frequency	Importance Value
Acacia thailandica	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Aeschynomene aspera	6.00000	0.01767	0.00408	0.00419	4.00000	0.10526	4.23765
Albizia saman	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Annona sp.	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Antidesma cochinchinensis	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Antidesma ghaesembilla	3.50000	0.01031	0.00712	0.00732	3.00000	0.07895	3.21925
aw krawpeuh	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
bai krium	0.50000	0.00147	0.00008	0.00008	1.00000	0.02632	0.92898
banlah dei suhut	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Barringtonia acutangula	0.50000	0.00147	0.00031	0.00032	1.00000	0.02632	0.93705
Bombax ceiba	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Borassus flabellifer	0.50000	0.00147	0.15904	0.16356	1.00000	0.02632	6.37825
Breynia sp.	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Bridelia ovata subsp. curtisii	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Capparis sp.	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Carica papaya	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Cayratia carnosa	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Ceiba pentandra	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
chleuy	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
chomtooal bong moan	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Chromolaena odorata	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
chuung buah	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Combretum trifoliatum	19.00000	0.05596	0.00840	0.00864	1.00000	0.02632	3.03076
Crateva adansonii subsp. odora	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Cratoxylum cochinchinense	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Croton sp.	21.50000	0.06333	0.00793	0.00816	1.00000	0.02632	3.26007
Croton sp.	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
daum bat leuh	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Dendrolobium sp.	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
dombai	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Dysoxylum procerum	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Eriobotrya bengalensis	39.50000	0.11635	0.01704	0.01753	5.00000	0.13158	8.84845
Feroniella lucida	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Gmelina asiatica	193.00000	0.56848	0.05159	0.05305	14.00000	0.36842	32.99848
Hymenocardia wallichii	1.50000	0.00442	0.00024	0.00024	1.00000	0.02632	1.03255
Jatropha curcas	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
kasoouah	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
kawtooul	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
kbah prei	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
kbuht	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
knai moan	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
kompleang	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
mreah preu	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
nyeeah	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
nyo	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Peltophorum	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Pithecellobium dulce	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Sesbania javanica	17.00000	0.05007	0.01695	0.01743	2.00000	0.05263	4.00438
Solanum sp.	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Solanum torvum	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Stephegyne parvifolia	34.50000	0.10162	0.69561	0.71536	2.00000	0.05263	28.98698
Streblus asper	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
swai kteeh	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Tamarindus indica	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Terminalia cambodiana	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
tlaum andauk	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Vitex holoadenon	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
voah preng	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Zizyphus mauritiana	2.50000	0.00736	0.00401	0.00412	2.00000	0.05263	2.13715
Zizyphus oenoplia	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

Appendix 4a-d: Importance Value Calculations

Herbaceous Species by Land Use/Land Cover Class

Appendix 4a: Importance Value Calculations, LULC Class Shrubland

Species	Cover Sum	Relative Cover Sum	Plot Frequency	Relative Plot Frequency	Importance Value
Achyranthes aspera	0	0.00000	0	0.00000	0.00000
Amaranthus spinosus	0	0.00000	0	0.00000	0.00000
Amaranthus viridis	0	0.00000	0	0.00000	0.00000
ampul prawk playee	0	0.00000	0	0.00000	0.00000
andaht buah	15	0.00943	2	0.02128	1.53553
Argyreia obtecta	0	0.00000	0	0.00000	0.00000
bok moat trei andaing	0	0.00000	0	0.00000	0.00000
Centella asiatica	0	0.00000	0	0.00000	0.00000
cheem	0	0.00000	0	0.00000	0.00000
chinchien momeeh	0	0.00000	0	0.00000	0.00000
chinchien sai	0	0.00000	0	0.00000	0.00000
chinchien tuk	15	0.00943	2	0.02128	1.53553
chnook troo	90	0.05660	2	0.02128	3.89402
chongkrong chap	0	0.00000	0	0.00000	0.00000
chplang	0	0.00000	0	0.00000	0.00000
chplang awnlooung	0	0.00000	0	0.00000	0.00000
chplang momeeh	0	0.00000	0	0.00000	0.00000
Chrysopogon aciculatus	0	0.00000	0	0.00000	0.00000
Coldenia procumbens	20	0.01258	3	0.03191	2.22468
Cynodon dactylon	10	0.00629	1	0.01064	0.84638
Cynodon sp.	10	0.00629	2	0.02128	1.37830
Cyperus cyperoides	5	0.00314	1	0.01064	0.68915
Cyperus kyllingia	10	0.00629	2	0.02128	1.37830
Cyperus rotundus	0	0.00000	0	0.00000	0.00000
daum aich cherook	0	0.00000	0	0.00000	0.00000
Desmodium triflorum	0	0.00000	0	0.00000	0.00000
dombei damrei	0	0.00000	0	0.00000	0.00000
dombei krawbei	10	0.00629	2	0.02128	1.37830
dombowie chkai	0	0.00000	0	0.00000	0.00000
Echinochloa crus-galli	0	0.00000	0	0.00000	0.00000
Eleusine indica	5	0.00314	1	0.01064	0.68915
Gomphrena globosa	0	0.00000	0	0.00000	0.00000
Heliotropium indicum	0	0.00000	0	0.00000	0.00000
Holarrhea pubescens	0	0.00000	0	0.00000	0.00000
Illicium sp.	0	0.00000	0	0.00000	0.00000
Impatiens relaxata	0	0.00000	0	0.00000	0.00000
Ipomoea aquatica	0	0.00000	0	0.00000	0.00000
Ipomoea sp.	0	0.00000	0	0.00000	0.00000
jeung tien	0	0.00000	0	0.00000	0.00000
jeung tokay nyee	5	0.00314	1	0.01064	0.68915
kadeuung bai saw	0	0.00000	0	0.00000	0.00000
kandaol bat	0	0.00000	0	0.00000	0.00000
kawlung kawlooung	0	0.00000	0	0.00000	0.00000
kawntrooie	0	0.00000	0	0.00000	0.00000
kbuht jooun	0	0.00000	0	0.00000	0.00000
kok	5	0.00314	1	0.01064	0.68915
kok cherung	0	0.00000	0	0.00000	0.00000
kok cheyn meyn	95	0.05975	7	0.07447	6.71083
kombai krawbei	0	0.00000	0	0.00000	0.00000
kombao	0	0.00000	0	0.00000	0.00000
kombao momeeh	0	0.00000	0	0.00000	0.00000
kombauwie krawbei	0	0.00000	0	0.00000	0.00000
kondieu	0	0.00000	0	0.00000	0.00000
krawchap chap	0	0.00000	0	0.00000	0.00000
kreung tee	0	0.00000	0	0.00000	0.00000
kwien kvahn	0	0.00000	0	0.00000	0.00000
Lagenaria siceraria	0	0.00000	0	0.00000	0.00000
Limnophila chinensis ssp. aromatica	0	0.00000	0	0.00000	0.00000
Limnophila repens	0	0.00000	0	0.00000	0.00000
lpeak tuk	0	0.00000	0	0.00000	0.00000
Ludwigia adscandens	25	0.01572	4	0.04255	2.91382
Lygodium flexuosum	0	0.00000	0	0.00000	0.00000
Marselia quadrifolia	10	0.00629	2	0.02128	1.37830
Mazus japonicus	0	0.00000	0	0.00000	0.00000
Merremia hederacea	10	0.00629	2	0.02128	1.37830
momeeh	0	0.00000	0	0.00000	0.00000
momeeng kmoung	0	0.00000	0	0.00000	0.00000
momun	0	0.00000	0	0.00000	0.00000
njohk tuk	0	0.00000	0	0.00000	0.00000
nokieah dei	0	0.00000	0	0.00000	0.00000
nyo chmol	0	0.00000	0	0.00000	0.00000
Pentapetes phoenica	0	0.00000	0	0.00000	0.00000
Phyllanthus urinaria	0	0.00000	0	0.00000	0.00000
pkah nmahl	0	0.00000	0	0.00000	0.00000
plang kok	0	0.00000	0	0.00000	0.00000
plang laung tuk	0	0.00000	0	0.00000	0.00000
plang momeeh	0	0.00000	0	0.00000	0.00000
plang tom	0	0.00000	0	0.00000	0.00000
plang tuk	0	0.00000	0	0.00000	0.00000
Polygonum tomentosum	105	0.06604	4	0.04255	5.42955
Portulaca quadrifolia	0	0.00000	0	0.00000	0.00000
praklop	0	0.00000	0	0.00000	0.00000

Appendix 4a: Importance Value Calculations, LULC Class Shrubland

Species	Cover Sum	Relative Cover Sum	Plot Frequency	Relative Plot Frequency	Importance Value
prawk andauk	100	0.06289	3	0.03191	4.74040
priel	0	0.00000	0	0.00000	0.00000
ptee banlah	0	0.00000	0	0.00000	0.00000
Quiqualis indica	0	0.00000	0	0.00000	0.00000
sandaich duk	0	0.00000	0	0.00000	0.00000
sarai tom	0	0.00000	0	0.00000	0.00000
sarai tom 2	0	0.00000	0	0.00000	0.00000
sawsuht	0	0.00000	0	0.00000	0.00000
sbai tuk	0	0.00000	0	0.00000	0.00000
sbauv	0	0.00000	0	0.00000	0.00000
sbauv aich moan	85	0.05346	3	0.03191	4.26870
sbauv andah	30	0.01887	2	0.02128	2.00723
sbauv pleang	50	0.03145	1	0.01064	2.10424
Sida acuta	0	0.00000	0	0.00000	0.00000
sluk rholooung	0	0.00000	0	0.00000	0.00000
sluk russei	165	0.10377	7	0.07447	8.91208
smau aich moan	0	0.00000	0	0.00000	0.00000
smau daik	0	0.00000	0	0.00000	0.00000
smau kawntooie krachok	0	0.00000	0	0.00000	0.00000
smau momeeh	0	0.00000	0	0.00000	0.00000
smaung	300	0.18868	10	0.10638	14.75311
somoung	0	0.00000	0	0.00000	0.00000
srauv	0	0.00000	0	0.00000	0.00000
srawngai	0	0.00000	0	0.00000	0.00000
srawngai kdeaung	0	0.00000	0	0.00000	0.00000
srawngai thom	0	0.00000	0	0.00000	0.00000
tanat loyin	0	0.00000	0	0.00000	0.00000
tawmbok	0	0.00000	0	0.00000	0.00000
tawsut	0	0.00000	0	0.00000	0.00000
Tephrosia purpurea	0	0.00000	0	0.00000	0.00000
Ternstroemia penangiana	0	0.00000	0	0.00000	0.00000
tkah	0	0.00000	0	0.00000	0.00000
tombayee krawbei	0	0.00000	0	0.00000	0.00000
traing	100	0.06289	2	0.02128	4.20848
traing knah	75	0.04717	1	0.01064	2.89041
trawkay lok	0	0.00000	0	0.00000	0.00000
trawsout loyn	0	0.00000	0	0.00000	0.00000
trop kmauich	0	0.00000	0	0.00000	0.00000
trup bai	0	0.00000	0	0.00000	0.00000
Utricularia sp.	0	0.00000	0	0.00000	0.00000
Vetivera zizanoides	10	0.00629	1	0.01064	0.84638
voah andaht trawkoouht	0	0.00000	0	0.00000	0.00000
voah dong preah	45	0.02830	9	0.09574	6.20233
voah lep	0	0.00000	0	0.00000	0.00000
voah preng	160	0.10063	11	0.11702	10.88251
voah sluk bei	0	0.00000	0	0.00000	0.00000
voah sluk bi	5	0.00314	1	0.01064	0.68915
voah sluk brai	0	0.00000	0	0.00000	0.00000
voah tadaht	0	0.00000	0	0.00000	0.00000
voah tuk dawh	20	0.01258	4	0.04255	2.75659
Xyris indica	0	0.00000	0	0.00000	0.00000

Appendix 4b: Importance Value Calculations, LULC Class Grassland

Species	Cover Sum	Relative Cover Sum	Plot Frequency	Relative Plot Frequency	Importance Value
Achyranthes aspera	0	0.00000	0	0.00000	0.00000
Amaranthus spinosus	0	0.00000	0	0.00000	0.00000
Amaranthus viridis	0	0.00000	0	0.00000	0.00000
ampul prawk playee	0	0.00000	0	0.00000	0.00000
andaht buah	95	0.00808	18	0.02844	1.82571
Argyreia obtecta	0	0.00000	0	0.00000	0.00000
bok moat trei andaing	0	0.00000	0	0.00000	0.00000
Centella asiatica	0	0.00000	0	0.00000	0.00000
cheem	0	0.00000	0	0.00000	0.00000
chinchien momeeh	0	0.00000	0	0.00000	0.00000
chinchien sai	0	0.00000	0	0.00000	0.00000
chinchien tuk	5	0.00043	1	0.00158	0.10025
chnook troo	1445	0.12287	35	0.05529	8.90832
chongkrong chap	0	0.00000	0	0.00000	0.00000
chplang	10	0.00085	2	0.00316	0.20049
chplang awnlooung	0	0.00000	0	0.00000	0.00000
chplang momeeh	175	0.01488	5	0.00790	1.13899
Chrysopogon aciculatus	0	0.00000	0	0.00000	0.00000
Coldenia procumbens	230	0.01956	30	0.04739	3.34756
Cynodon dactylon	695	0.05910	18	0.02844	4.37673
Cynodon sp.	55	0.00468	6	0.00948	0.70778
Cyperus cyperoides	0	0.00000	0	0.00000	0.00000
Cyperus kyllingia	15	0.00128	2	0.00316	0.22175
Cyperus rotundus	0	0.00000	0	0.00000	0.00000
daum aich cherook	0	0.00000	0	0.00000	0.00000
Desmodium triflorum	0	0.00000	0	0.00000	0.00000
dombei damrei	0	0.00000	0	0.00000	0.00000
dombei krawbei	10	0.00085	2	0.00316	0.20049
dombowie chkai	30	0.00255	4	0.00632	0.44351
Echinochloa crus-galli	290	0.02466	31	0.04897	3.68165
Eleusine indica	50	0.00425	5	0.00790	0.60753
Gomphrena globosa	0	0.00000	0	0.00000	0.00000
Heliotropium indicum	0	0.00000	0	0.00000	0.00000
Holarrhea pubescens	0	0.00000	0	0.00000	0.00000
Illicium sp.	0	0.00000	0	0.00000	0.00000
Impatiens relaxata	150	0.01276	2	0.00316	0.79573
Ipomoea aquatica	5	0.00043	1	0.00158	0.10025
Ipomoea sp.	0	0.00000	0	0.00000	0.00000
jeung tien	205	0.01743	28	0.04423	3.08329
jeung tokay nyee	15	0.00128	2	0.00316	0.22175
kadeuung bai saw	0	0.00000	0	0.00000	0.00000
kandaol bat	0	0.00000	0	0.00000	0.00000
kawlung kawlooung	25	0.00213	4	0.00632	0.42225
kawntrooie	0	0.00000	0	0.00000	0.00000
kbuht jooun	0	0.00000	0	0.00000	0.00000
kok	5	0.00043	1	0.00158	0.10025
kok cherung	10	0.00085	1	0.00158	0.12151
kok cheyn meyn	305	0.02594	27	0.04265	3.42947
kombai krawbei	0	0.00000	0	0.00000	0.00000
kombao	350	0.02976	18	0.02844	2.90990
kombao momeeh	0	0.00000	0	0.00000	0.00000
kombauwie krawbei	0	0.00000	0	0.00000	0.00000
kondieu	10	0.00085	2	0.00316	0.20049
krawchap chap	0	0.00000	0	0.00000	0.00000
kreung tee	5	0.00043	1	0.00158	0.10025
kwien kvahn	0	0.00000	0	0.00000	0.00000
Lagenaria siceraria	0	0.00000	0	0.00000	0.00000
Limnophila chinensis ssp. aromatica	0	0.00000	0	0.00000	0.00000
Limnophila repens	55	0.00468	7	0.01106	0.78677
lpeak tuk	70	0.00595	11	0.01738	1.16650
Ludwigia adscandens	20	0.00170	4	0.00632	0.40099
Lygodium flexuosum	5	0.00043	1	0.00158	0.10025
Marselia quadrifolia	0	0.00000	0	0.00000	0.00000
Mazus japonicus	0	0.00000	0	0.00000	0.00000
Merremia hederacea	175	0.01488	22	0.03476	2.48180
momeeh	40	0.00340	7	0.01106	0.72299
momeeng kmoung	0	0.00000	0	0.00000	0.00000
momun	0	0.00000	0	0.00000	0.00000
njohk tuk	5	0.00043	1	0.00158	0.10025
nokieah dei	0	0.00000	0	0.00000	0.00000
nyo chmol	10	0.00085	2	0.00316	0.20049
Pentapetes phoenica	0	0.00000	0	0.00000	0.00000
Phyllanthus urinaria	0	0.00000	0	0.00000	0.00000
pkah nmahl	0	0.00000	0	0.00000	0.00000
plang kok	115	0.00978	6	0.00948	0.96288
plang laung tuk	30	0.00255	4	0.00632	0.44351
plang momeeh	30	0.00255	6	0.00948	0.60148
plang tom	110	0.00935	19	0.03002	1.96848
plang tuk	45	0.00383	3	0.00474	0.42829
Polygonum tomentosum	200	0.01701	2	0.00316	1.00832
Portulaca quadrifolia	0	0.00000	0	0.00000	0.00000
praklop	0	0.00000	0	0.00000	0.00000

Appendix 4b: Importance Value Calculations, LULC Class Grassland

Species	Cover Sum	Relative Cover Sum	Plot Frequency	Relative Plot Frequency	Importance Value
prawk andauk	1055	0.08971	49	0.07741	8.35600
priel	0	0.00000	0	0.00000	0.00000
ptee banlah	0	0.00000	0	0.00000	0.00000
Quiqualis indica	30	0.00255	1	0.00158	0.20654
sandaich duk	0	0.00000	0	0.00000	0.00000
sarai tom	135	0.01148	9	0.01422	1.28488
sarai tom 2	5	0.00043	1	0.00158	0.10025
sawsuht	0	0.00000	0	0.00000	0.00000
sbai tuk	5	0.00043	1	0.00158	0.10025
sbauv	0	0.00000	0	0.00000	0.00000
sbauv aich moan	0	0.00000	0	0.00000	0.00000
sbauv andah	320	0.02721	16	0.02528	2.62437
sbauv pleang	285	0.02423	16	0.02528	2.47556
Sida acuta	0	0.00000	0	0.00000	0.00000
sluk rholooung	0	0.00000	0	0.00000	0.00000
sluk russei	815	0.06930	26	0.04107	5.51885
smau aich moan	20	0.00170	1	0.00158	0.16402
smau daik	0	0.00000	0	0.00000	0.00000
smau kawntooie krachok	0	0.00000	0	0.00000	0.00000
smau momeeh	0	0.00000	0	0.00000	0.00000
smaung	730	0.06207	16	0.02528	4.36756
somoung	1605	0.13648	39	0.06161	9.90455
srauv	0	0.00000	0	0.00000	0.00000
srawngai	60	0.00510	4	0.00632	0.57106
srawngai kdeaung	0	0.00000	0	0.00000	0.00000
srawngai thom	0	0.00000	0	0.00000	0.00000
tanat loyin	180	0.01531	15	0.02370	1.95014
tawmbok	0	0.00000	0	0.00000	0.00000
tawsut	165	0.01403	15	0.02370	1.88636
Tephrosia purpurea	0	0.00000	0	0.00000	0.00000
Ternstroemia penangiana	20	0.00170	4	0.00632	0.40099
tkah	160	0.01361	14	0.02212	1.78612
tombayee krawbei	0	0.00000	0	0.00000	0.00000
traing	295	0.02509	5	0.00790	1.64920
traing knah	195	0.01658	5	0.00790	1.22403
trawkay lok	0	0.00000	0	0.00000	0.00000
trawsout loyn	0	0.00000	0	0.00000	0.00000
trop kmauich	0	0.00000	0	0.00000	0.00000
trup bai	0	0.00000	0	0.00000	0.00000
Utricularia sp.	30	0.00255	1	0.00158	0.20654
Vetivera zizanoides	260	0.02211	16	0.02528	2.36927
voah andaht trawkoouht	5	0.00043	1	0.00158	0.10025
voah dong preah	200	0.01701	25	0.03949	2.82506
voah lep	0	0.00000	0	0.00000	0.00000
voah preng	10	0.00085	2	0.00316	0.20049
voah sluk bei	0	0.00000	0	0.00000	0.00000
voah sluk bi	0	0.00000	0	0.00000	0.00000
voah sluk brai	0	0.00000	0	0.00000	0.00000
voah tadaht	5	0.00043	1	0.00158	0.10025
voah tuk dawh	10	0.00085	2	0.00316	0.20049
Xyris indica	60	0.00510	7	0.01106	0.80802

Appendix 4c: Importance Value Calculations, LULC Class Hillock

Species	Cover Sum	Relative Cover Sum	Plot Frequency	Relative Plot Frequency	Importance Value
Achyranthes aspera	10	0.00194	2	0.00568	0.38127
Amaranthus spinosus	10	0.00194	1	0.00284	0.23923
Amaranthus viridis	20	0.00389	3	0.00852	0.62050
ampul prawk playee	5	0.00097	1	0.00284	0.19064
andaht buah	120	0.02332	10	0.02841	2.58664
Argyreia obtecta	5	0.00097	1	0.00284	0.19064
bok moat trei andaing	0	0.00000	0	0.00000	0.00000
Centella asiatica	0	0.00000	0	0.00000	0.00000
cheem	0	0.00000	0	0.00000	0.00000
chinchien momeeh	20	0.00389	1	0.00284	0.33641
chinchien sai	10	0.00194	2	0.00568	0.38127
chinchien tuk	20	0.00389	1	0.00284	0.33641
chnook troo	100	0.01944	3	0.00852	1.39795
chongkrong chap	10	0.00194	2	0.00568	0.38127
chplang	0	0.00000	0	0.00000	0.00000
chplang awnlooung	5	0.00097	1	0.00284	0.19064
chplang momeeh	35	0.00680	6	0.01705	1.19241
Chrysopogon aciculatus	265	0.05151	7	0.01989	3.56963
Coldenia procumbens	80	0.01555	9	0.02557	2.05586
Cynodon dactylon	769	0.14947	37	0.10511	12.72896
Cynodon sp.	570	0.11079	26	0.07386	9.23254
Cyperus cyperoides	0	0.00000	0	0.00000	0.00000
Cyperus kyllingia	0	0.00000	0	0.00000	0.00000
Cyperus rotundus	640	0.12439	22	0.06250	9.34463
daum aich cherook	0	0.00000	0	0.00000	0.00000
Desmodium triflorum	0	0.00000	0	0.00000	0.00000
dombei damrei	0	0.00000	0	0.00000	0.00000
dombei krawbei	5	0.00097	1	0.00284	0.19064
dombowie chkai	0	0.00000	0	0.00000	0.00000
Echinochloa crus-galli	20	0.00389	4	0.01136	0.76255
Eleusine indica	539	0.10476	20	0.05682	8.07900
Gomphrena globosa	0	0.00000	0	0.00000	0.00000
Heliotropium indicum	44	0.00855	7	0.01989	1.42192
Holarrhea pubescens	5	0.00097	1	0.00284	0.19064
Illicium sp.	0	0.00000	0	0.00000	0.00000
Impatiens relaxata	0	0.00000	0	0.00000	0.00000
Ipomoea aquatica	30	0.00583	1	0.00284	0.43359
Ipomoea sp.	25	0.00486	4	0.01136	0.81114
jeung tien	0	0.00000	0	0.00000	0.00000
jeung tokay nyee	0	0.00000	0	0.00000	0.00000
kadeuung bai saw	20	0.00389	4	0.01136	0.76255
kandaol bat	85	0.01652	4	0.01136	1.39423
kawlung kawlooung	10	0.00194	2	0.00568	0.38127
kawntrooie	15	0.00292	2	0.00568	0.42986
kbuht jooun	50	0.00972	6	0.01705	1.33818
kok	0	0.00000	0	0.00000	0.00000
kok cherung	0	0.00000	0	0.00000	0.00000
kok cheyn meyn	10	0.00194	2	0.00568	0.38127
kombai krawbei	25	0.00486	5	0.01420	0.95318
kombao	5	0.00097	1	0.00284	0.19064
kombao momeeh	0	0.00000	0	0.00000	0.00000
kombauwie krawbei	0	0.00000	0	0.00000	0.00000
kondieu	5	0.00097	1	0.00284	0.19064
krawchap chap	0	0.00000	0	0.00000	0.00000
kreung tee	0	0.00000	0	0.00000	0.00000
kwien kvahn	5	0.00097	1	0.00284	0.19064
Lagenaria siceraria	5	0.00097	1	0.00284	0.19064
Limnophila chinensis ssp. aromatica	0	0.00000	0	0.00000	0.00000
Limnophila repens	30	0.00583	6	0.01705	1.14382
lpeak tuk	0	0.00000	0	0.00000	0.00000
Ludwigia adscandens	50	0.00972	8	0.02273	1.62227
Lygodium flexuosum	0	0.00000	0	0.00000	0.00000
Marselia quadrifolia	15	0.00292	3	0.00852	0.57191
Mazus japonicus	30	0.00583	2	0.00568	0.57564
Merremia hederacea	15	0.00292	3	0.00852	0.57191
momeeh	0	0.00000	0	0.00000	0.00000
momeeng kmoung	5	0.00097	1	0.00284	0.19064
momun	5	0.00097	1	0.00284	0.19064
njohk tuk	0	0.00000	0	0.00000	0.00000
nokieah dei	25	0.00486	2	0.00568	0.52705
nyo chmol	0	0.00000	0	0.00000	0.00000
Pentapetes phoenica	20	0.00389	4	0.01136	0.76255
Phyllanthus urinaria	10	0.00194	2	0.00568	0.38127
pkah nmahl	85	0.01652	7	0.01989	1.82036
plang kok	60	0.01166	5	0.01420	1.29332
plang laung tuk	0	0.00000	0	0.00000	0.00000
plang momeeh	20	0.00389	1	0.00284	0.33641
plang tom	0	0.00000	0	0.00000	0.00000
plang tuk	0	0.00000	0	0.00000	0.00000
Polygonum tomentosum	25	0.00486	4	0.01136	0.81114
Portulaca quadrifolia	20	0.00389	4	0.01136	0.76255
praklop	20	0.00389	4	0.01136	0.76255

Appendix 4c: Importance Value Calculations, LULC Class Hillock

Species	Cover Sum	Relative Cover Sum	Plot Frequency	Relative Plot Frequency	Importance Value
prawk andauk	0	0.00000	0	0.00000	0.00000
priel	0	0.00000	0	0.00000	0.00000
ptee banlah	5	0.00097	1	0.00284	0.19064
Quiqualis indica	60	0.01166	4	0.01136	1.15127
sandaich duk	15	0.00292	3	0.00852	0.57191
sarai tom	10	0.00194	2	0.00568	0.38127
sarai tom 2	0	0.00000	0	0.00000	0.00000
sawsuht	0	0.00000	0	0.00000	0.00000
sbai tuk	0	0.00000	0	0.00000	0.00000
sbauv	45	0.00875	2	0.00568	0.72141
sbauv aich moan	0	0.00000	0	0.00000	0.00000
sbauv andah	444	0.08630	15	0.04261	6.44555
sbauv pleang	5	0.00097	1	0.00284	0.19064
Sida acuta	25	0.00486	5	0.01420	0.95318
sluk rholooung	0	0.00000	0	0.00000	0.00000
sluk russei	104	0.02021	10	0.02841	2.43114
smau aich moan	0	0.00000	0	0.00000	0.00000
smau daik	25	0.00486	4	0.01136	0.81114
smau kawntooie krachok	0	0.00000	0	0.00000	0.00000
smau momeeh	5	0.00097	1	0.00284	0.19064
smaung	0	0.00000	0	0.00000	0.00000
somoung	0	0.00000	0	0.00000	0.00000
srauv	40	0.00777	3	0.00852	0.81486
srawngai	45	0.00875	2	0.00568	0.72141
srawngai kdeaung	0	0.00000	0	0.00000	0.00000
srawngai thom	45	0.00875	3	0.00852	0.86345
tanat loyin	20	0.00389	2	0.00568	0.47845
tawmbok	5	0.00097	1	0.00284	0.19064
tawsut	0	0.00000	0	0.00000	0.00000
Tephrosia purpurea	40	0.00777	8	0.02273	1.52509
Ternstroemia penangiana	0	0.00000	0	0.00000	0.00000
tkah	40	0.00777	1	0.00284	0.53077
tombayee krawbei	10	0.00194	2	0.00568	0.38127
traing	0	0.00000	0	0.00000	0.00000
traing knah	5	0.00097	1	0.00284	0.19064
trawkay lok	0	0.00000	0	0.00000	0.00000
trawsout loyn	5	0.00097	1	0.00284	0.19064
trop kmauich	5	0.00097	1	0.00284	0.19064
trup bai	5	0.00097	1	0.00284	0.19064
Utricularia sp.	0	0.00000	0	0.00000	0.00000
Vetivera zizanoides	25	0.00486	3	0.00852	0.66909
voah andaht trawkoouht	0	0.00000	0	0.00000	0.00000
voah dong preah	35	0.00680	7	0.01989	1.33445
voah lep	5	0.00097	1	0.00284	0.19064
voah preng	15	0.00292	3	0.00852	0.57191
voah sluk bei	0	0.00000	0	0.00000	0.00000
voah sluk bi	0	0.00000	0	0.00000	0.00000
voah sluk brai	5	0.00097	1	0.00284	0.19064
voah tadaht	0	0.00000	0	0.00000	0.00000
voah tuk dawh	10	0.00194	2	0.00568	0.38127
Xyris indica	10	0.00194	2	0.00568	0.38127

Appendix 4d: Importance Value Calculations, LULC Class Ricefield

Species	Cover Sum	Relative Cover Sum	Plot Frequency	Relative Plot Frequency	Importance Value
Achyranthes aspera	0	0.00000	0	0.00000	0.00000
Amaranthus spinosus	0	0.00000	0	0.00000	0.00000
Amaranthus viridis	0	0.00000	0	0.00000	0.00000
ampul prawk playee	0	0.00000	0	0.00000	0.00000
andaht buah	180	0.00185	21	0.03271	1.72822
Argyreia obtecta	0	0.00000	0	0.00000	0.00000
bok moat trei andaing	10	0.00000	2	0.00312	0.15576
Centella asiatica	5	0.00000	1	0.00156	0.07788
cheem	5	0.00000	1	0.00156	0.07788
chinchien momeeh	0	0.00000	0	0.00000	0.00000
chinchien sai	0	0.00000	0	0.00000	0.00000
chinchien tuk	15	0.00185	3	0.00467	0.32635
chnook troo	0	0.01112	0	0.00000	0.55624
chongkrong chap	15	0.00000	3	0.00467	0.23364
chplang	45	0.00000	5	0.00779	0.38941
chplang awnlooung	0	0.00000	0	0.00000	0.00000
chplang momeeh	190	0.00000	18	0.02804	1.40187
Chrysopogon aciculatus	0	0.00000	0	0.00000	0.00000
Coldenia procumbens	90	0.00247	13	0.02025	1.13607
Cynodon dactylon	805	0.00124	35	0.05452	2.78766
Cynodon sp.	990	0.00124	54	0.08411	4.26741
Cyperus cyperoides	5	0.00062	1	0.00156	0.10878
Cyperus kyllingia	0	0.00124	0	0.00000	0.06180
Cyperus rotundus	5	0.00000	1	0.00156	0.07788
daum aich cherook	5	0.00000	1	0.00156	0.07788
Desmodium triflorum	55	0.00000	5	0.00779	0.38941
dombei damrei	5	0.00000	1	0.00156	0.07788
dombei krawbei	25	0.00124	5	0.00779	0.45121
dombowie chkai	0	0.00000	0	0.00000	0.00000
Echinochloa crus-galli	100	0.00000	18	0.02804	1.40187
Eleusine indica	265	0.00062	23	0.03583	1.82218
Gomphrena globosa	40	0.00000	4	0.00623	0.31153
Heliotropium indicum	75	0.00000	9	0.01402	0.70093
Holarrhea pubescens	0	0.00000	0	0.00000	0.00000
Illicium sp.	20	0.00000	2	0.00312	0.15576
Impatiens relaxata	0	0.00000	0	0.00000	0.00000
Ipomoea aquatica	35	0.00000	6	0.00935	0.46729
Ipomoea sp.	90	0.00000	10	0.01558	0.77882
jeung tien	15	0.00000	3	0.00467	0.23364
jeung tokay nyee	0	0.00062	0	0.00000	0.03090
kadeuung bai saw	0	0.00000	0	0.00000	0.00000
kandaol bat	0	0.00000	0	0.00000	0.00000
kawlung kawlooung	0	0.00000	0	0.00000	0.00000
kawntrooie	0	0.00000	0	0.00000	0.00000
kbuht jooun	0	0.00000	0	0.00000	0.00000
kok	0	0.00062	0	0.00000	0.03090
kok cherung	0	0.00000	0	0.00000	0.00000
kok cheyn meyn	60	0.01174	12	0.01869	1.52172
kombai krawbei	20	0.00000	3	0.00467	0.23364
kombao	40	0.00000	5	0.00779	0.38941
kombao momeeh	5	0.00000	1	0.00156	0.07788
kombauwie krawbei	10	0.00000	2	0.00312	0.15576
kondieu	380	0.00000	15	0.02336	1.16822
krawchap chap	5	0.00000	1	0.00156	0.07788
kreung tee	0	0.00000	0	0.00000	0.00000
kwien kvahn	0	0.00000	0	0.00000	0.00000
Lagenaria siceraria	0	0.00000	0	0.00000	0.00000
Limnophila chinensis ssp. aromatica	20	0.00000	4	0.00623	0.31153
Limnophila repens	80	0.00000	14	0.02181	1.09034
lpeak tuk	0	0.00000	0	0.00000	0.00000
Ludwigia adscandens	240	0.00309	12	0.01869	1.08909
Lygodium flexuosum	0	0.00000	0	0.00000	0.00000
Marselia quadrifolia	0	0.00124	0	0.00000	0.06180
Mazus japonicus	15	0.00000	1	0.00156	0.07788
Merremia hederacea	140	0.00124	26	0.04050	2.08673
momeeh	80	0.00000	9	0.01402	0.70093
momeeng kmoung	0	0.00000	0	0.00000	0.00000
momun	0	0.00000	0	0.00000	0.00000
njohk tuk	0	0.00000	0	0.00000	0.00000
nokieah dei	0	0.00000	0	0.00000	0.00000
nyo chmol	0	0.00000	0	0.00000	0.00000
Oryza sativa	200	0.00000	14	0.02181	1.09034
Pentapetes phoenica	65	0.00000	13	0.02025	1.01246
Phyllanthus urinaria	0	0.00000	0	0.00000	0.00000
pkah nmahl	20	0.00000	4	0.00623	0.31153
plang kok	400	0.00000	17	0.02648	1.32399
plang laung tuk	230	0.00000	12	0.01869	0.93458
plang momeeh	190	0.00000	8	0.01246	0.62305
plang tom	45	0.00000	8	0.01246	0.62305
plang tuk	15	0.00000	2	0.00312	0.15576
Polygonum tomentosum	205	0.01298	6	0.00935	1.11624
Portulaca quadrifolia	0	0.00000	0	0.00000	0.00000

Appendix 4d: Importance Value Calculations, LULC Class Ricefield

Species	Cover Sum	Relative Cover Sum	Plot Frequency	Relative Plot Frequency	Importance Value
praklop	0	0.00000	0	0.00000	0.00000
prawk andauk	225	0.01236	23	0.03583	2.40932
priel	5	0.00000	1	0.00156	0.07788
ptee banlah	0	0.00000	0	0.00000	0.00000
Quiqualis indica	45	0.00000	3	0.00467	0.23364
sandaich duk	0	0.00000	0	0.00000	0.00000
sarai tom	0	0.00000	0	0.00000	0.00000
sarai tom 2	0	0.00000	0	0.00000	0.00000
sawsuht	10	0.00000	2	0.00312	0.15576
sbai tuk	0	0.00000	0	0.00000	0.00000
sbauv	10	0.00000	2	0.00312	0.15576
sbauv aich moan	0	0.01051	0	0.00000	0.52534
sbauv andah	25	0.00371	3	0.00467	0.41906
sbauv pleang	10	0.00618	1	0.00156	0.38691
Sida acuta	0	0.00000	0	0.00000	0.00000
sluk rholooung	5	0.00000	1	0.00156	0.07788
sluk russei	285	0.02040	17	0.02648	2.34377
smau aich moan	0	0.00000	0	0.00000	0.00000
smau daik	0	0.00000	0	0.00000	0.00000
smau kawntooie krachok	20	0.00000	1	0.00156	0.07788
smau momeeh	0	0.00000	0	0.00000	0.00000
smaung	105	0.03708	9	0.01402	2.55508
somoung	180	0.00000	5	0.00779	0.38941
srawngai	330	0.00000	15	0.02336	1.16822
srawngai kdeaung	75	0.00000	4	0.00623	0.31153
srawngai thom	30	0.00000	1	0.00156	0.07788
tanat loyin	125	0.00000	17	0.02648	1.32399
tawmbok	0	0.00000	0	0.00000	0.00000
tawsut	5	0.00000	1	0.00156	0.07788
Tephrosia purpurea	0	0.00000	0	0.00000	0.00000
Ternstroemia penangiana	20	0.00000	3	0.00467	0.23364
tkah	560	0.00000	48	0.07477	3.73832
tombayee krawbei	15	0.00000	3	0.00467	0.23364
traing	0	0.01236	0	0.00000	0.61805
traing knah	0	0.00927	0	0.00000	0.46354
trawkay lok	10	0.00000	2	0.00312	0.15576
trawsout loyn	0	0.00000	0	0.00000	0.00000
trop kmauich	0	0.00000	0	0.00000	0.00000
trup bai	0	0.00000	0	0.00000	0.00000
Utricularia sp.	0	0.00000	0	0.00000	0.00000
Vetivera zizanoides	280	0.00124	18	0.02804	1.46367
voah andaht trawkoouht	0	0.00000	0	0.00000	0.00000
voah dong preah	10	0.00556	2	0.00312	0.43388
voah lep	0	0.00000	0	0.00000	0.00000
voah preng	5	0.01978	1	0.00156	1.06676
voah sluk bei	20	0.00000	3	0.00467	0.23364
voah sluk bi	5	0.00062	1	0.00156	0.10878
voah sluk brai	0	0.00000	1	0.00156	0.07788
voah tadaht	0	0.00000	0	0.00000	0.00000
voah tuk dawh	0	0.00247	2	0.00312	0.27937
Xyris indica	120	0.00000	18	0.02804	1.40187

Appendix 5: Relevé Table

Appendix 5: Relevé Table. Species are sorted first by the number of land use/land cover classes in which they occur, from most widespread to least, followed by their importance value for each land use/land cover class. Plants not yet determined to species are identified by their common names (in italics).

	Importance Values by LULC Class					
Name	**Grassland**	**Shrubland**	**Ricefield**	**Hillock**	**# LULC Classes**	**Stratum**
Gmelina asiatica	9.51410	25.73740	16.49920	5.21160	4	Canopy
Barringtonia acutangula	7.93120	5.75440	0.46850	2.43760	4	Canopy
Hymenocardia wallichii	6.00170	2.52200	0.51630	2.32590	4	Canopy
chnook troo	4.45420	1.94700	0.27810	0.69900	4	Understory
Croton sp.	4.26600	5.38770	1.63000	4.46160	4	Canopy
sluk russei	2.75940	4.45600	1.17190	1.21560	4	Understory
Cynodon dactylon	2.18840	0.42320	1.39380	6.36450	4	Understory
Stephegyne parvifolia	2.06270	0.15600	14.49350	1.79720	4	Canopy
kok cheyn meyn	1.71470	3.35540	0.76090	0.19060	4	Understory
Coldenia procumbens	1.67380	1.11230	0.56800	1.02790	4	Understory
voah dong preah	1.41250	3.10120	0.21690	0.66720	4	Understory
sbauv andah	1.31220	1.00360	0.20950	3.22280	4	Understory
bai krium	1.25130	0.28750	0.46450	0.14630	4	Canopy
Merremia hederacea	1.24090	0.68910	1.04340	0.28600	4	Understory
sbauv pleang	1.23780	1.05210	0.19350	0.09530	4	Understory
Vetivera	1.18460	0.42320	0.73180	0.33450	4	Understory
andaht buah	0.91290	0.76780	0.86410	1.29330	4	Understory
Antidesma ghaesembilla	0.72240	0.70280	1.60960	1.02890	4	Canopy
traing knah	0.61200	1.44520	0.23180	0.09530	4	Understory
Polygonum tomentosum	0.50420	2.71480	0.55810	0.40560	4	Understory
Cynodon sp.	0.35390	0.68910	2.13370	4.61630	4	Understory
Eleusine indica	0.30380	0.34460	0.91110	4.03950	4	Understory
Ludwigia adscandens	0.20050	1.45690	0.54450	0.81110	4	Understory
voah preng	0.10020	5.44130	0.53340	0.28600	4	Understory
voah tuk dawh	0.10020	1.37830	0.13970	0.19060	4	Understory
dombei krawbei	0.10020	0.68910	0.22560	0.09530	4	Understory
chinchien tuk	0.05010	0.76780	0.16320	0.16820	4	Understory
prawk andauk	4.17800	2.37020	1.20470		3	Understory
smaung	2.18380	7.37660	1.27750		3	Understory
Dysoxylum procerum	2.17530	1.35980		1.34450	3	Canopy
Echinochloa crus-galli	1.84080		0.70090	0.38130	3	Understory
kombao	1.45490		0.19470	0.09530	3	Understory
tlaum andauk	1.31380	2.37650		0.11910	3	Canopy
tanat loyin	0.97510		0.66200	0.23920	3	Understory
tkah	0.89310		1.86920	0.26540	3	Understory
traing	0.82460	2.10420	0.30900		3	Understory
Dendrolobium sp.	0.58920	0.88270		1.03390	3	Canopy
chplang momeeh	0.56950		0.70090	0.59620	3	Understory
nyo	0.50780	0.53580		0.13270	3	Canopy
plang kok	0.48140		0.66200	0.64670	3	Understory
Xyris indica	0.40400		0.70090	0.19060	3	Understory
Limnophila repens	0.39340		0.54520	0.57190	3	Understory
knai moan	0.32920	0.14790		0.13600	3	Canopy
plang momeeh	0.30070		0.31150	0.16820	3	Understory
Oryza rufipogon	0.28550		0.58410	0.36070	3	Understory
Eriobotrya bengalensis	0.15320	0.13720	4.42420		3	Canopy

Importance Values by LULC Class

Name	Grassland	Shrubland	Ricefield	Hillock	# LULC Classes	Stratum
Cyperus kyllingia	0.11090	0.68910	0.03090		3	Understory
jeung tokay nyee	0.11090	0.34460	0.01550		3	Understory
Quiqualis indica	0.10330		0.11680	0.57560	3	Understory
kondieu	0.10020		0.58410	0.09530	3	Understory
Cyperus cyperoides	0.05010	0.34460	0.01550		3	Understory
Ipomoea aquatica	0.05010		0.23360	0.21680	3	Understory
Marselia quadrifolia		0.68910	0.03090	0.28600	3	Understory
Combretum trifoliatum		0.35630	1.51540	0.12290	3	Canopy
somoung	4.95230		0.19470		2	Understory
jeung tien	1.54160		0.11680		2	Understory
Sesbania javanica	1.25780		2.00220		2	Canopy
plang tom	0.98420		0.31150		2	Understory
tawsut	0.94320		0.03890		2	Understory
sarai tom	0.64240			0.19060	2	Understory
Bridelia ovata	0.48830			1.04370	2	Canopy
momeeh	0.36150		0.35050		2	Understory
plang laung tuk	0.22180		0.46730		2	Understory
plang tuk	0.21410		0.07790		2	Understory
kawlung kawlooung	0.21110			0.19060	2	Understory
Ternstroemia penangiana	0.20050		0.11680		2	Understory
kasoouah	0.13820			0.27220	2	Canopy
kbah prei	0.12980	0.31860			2	Canopy
dombai	0.12290			0.11230	2	Canopy
Peltophorum sp.	0.11050			3.46020	2	Canopy
aw krawpeuh	0.11050			0.35970	2	Canopy
chplang	0.10020		0.19470		2	Understory
sbauv aich moan		2.13440	0.26270		2	Understory
voah sluk bi		0.34460	0.05440		2	Understory
smau kok		0.34460	0.05440		2	Understory
Aeschynomene aspera		0.26300	2.11880		2	Canopy
Borassus flabellifer			3.18910	1.00080	2	Canopy
Zizyphus mauritiana			1.06860	3.35030	2	Canopy
Oryza sativa			0.54520	0.40740	2	Understory
Pentapetes phoenica			0.50620	0.38130	2	Understory
trawkoon trawkaich			0.38940	0.40560	2	Understory
Heliotropium indicum			0.35050	0.71100	2	Understory
pkah nmahl			0.15580	0.91020	2	Understory
kombai krawbei			0.11680	0.47660	2	Understory
tombayee krawbei			0.11680	0.19060	2	Understory
chongkrong chap			0.11680	0.19060	2	Understory
sbauv			0.07790	0.36070	2	Understory
Cyperus rotundus			0.03890	4.67230	2	Understory
srawngai thom			0.03890	0.43170	2	Understory
Mazus japonicus			0.03890	0.28780	2	Understory
voah sluk brai			0.03890	0.09530	2	Understory
lpeak tuk	0.58320				1	Understory
chomtooal bong moan	0.54400				1	Canopy
Terminalia cambodiana	0.53490				1	Canopy
Impatiens relaxata	0.39790				1	Understory
dombowie chkai	0.22180				1	Understory
chleuy	0.11810				1	Canopy
chuung buah	0.11330				1	Canopy

Importance Values by LULC Class

Name	Grassland	Shrubland	Ricefield	Hillock	# LULC Classes	Stratum
sarai	0.10330				1	Understory
nyo chmol	0.10020				1	Understory
smau aich moan	0.08200				1	Understory
kok cherung	0.06080				1	Understory
kreung tee	0.05010				1	Understory
njohk tuk	0.05010				1	Understory
sarai tom 2	0.05010				1	Understory
sbai tuk	0.05010				1	Understory
voah andaht trawkoouht	0.05010				1	Understory
Lygodium flexuosum	0.05010				1	Understory
voah tadaht	0.05010				1	Understory
Vitex holoadenon		1.70960			1	Canopy
Cratoxylum cochinchinense		0.65740			1	Canopy
nyeeah		0.15440			1	Canopy
Acacia thailandica		0.14460			1	Canopy
kompleang		0.14240			1	Canopy
kawtooul		0.13800			1	Canopy
Croton sp.		0.12780			1	Canopy
Desmodium triflorum			0.19470		1	Understory
Limnophila chinensis			0.15580		1	Understory
Gomphrena globosa			0.15580		1	Understory
srawngai kdeaung			0.15580		1	Understory
voah sluk bei			0.11680		1	Understory
bok moat trei andaing			0.07790		1	Understory
kombauwie krawbei			0.07790		1	Understory
Illicium sp.			0.07790		1	Understory
sawsuht			0.07790		1	Understory
trawkay lok			0.07790		1	Understory
cheem			0.03890		1	Understory
daum aich cherook			0.03890		1	Understory
dombei damrei			0.03890		1	Understory
Centella asiatica			0.03890		1	Understory
kombao momeeh			0.03890		1	Understory
krawchap chap			0.03890		1	Understory
priel			0.03890		1	Understory
sluk rholooung			0.03890		1	Understory
smau kawntooie krachok			0.03890		1	Understory
Jatropha curcas				4.43190	1	Canopy
Chromolaena odorata				3.16580	1	Canopy
Feroniella lucida				2.68750	1	Canopy
Chrysopogon aciculatus				1.78480	1	Understory
Albizia saman				1.54920	1	Canopy
Ceiba pentandra				1.28490	1	Canopy
Pithecellobium dulce				0.95220	1	Canopy
Zizyphus oenoplia				0.90670	1	Canopy
Bombax ceiba				0.88000	1	Canopy
trem kmauich				0.76250	1	Understory
kandaol bat				0.69710	1	Understory
kbuht jooun				0.66910	1	Understory
Crateva adansonii				0.62440	1	Canopy
Cayratia carnosa				0.61410	1	Canopy
Sida acuta				0.47660	1	Understory

Importance Values by LULC Class

Name	Grassland	Shrubland	Ricefield	Hillock	# LULC Classes	Stratum
smau daik				0.40560	1	Understory
Carica papaya				0.40440	1	Canopy
Streblus asper				0.40140	1	Canopy
Breynia sp.				0.39020	1	Canopy
Portulaca quadrifolia				0.38130	1	Understory
praklop				0.38130	1	Understory
kadeuung bai saw				0.38130	1	Understory
Capparis sp.				0.35030	1	Canopy
Amaranthus viridis				0.31020	1	Understory
sandaich duk				0.28600	1	Understory
nokieah dei				0.26350	1	Understory
kawntrooie				0.21490	1	Understory
Phyllanthus urinaria				0.19060	1	Understory
chinchien sai				0.19060	1	Understory
andaht ko				0.19060	1	Understory
Antidesma cochinchinensis				0.18290	1	Canopy
chinchien momeeh				0.16820	1	Understory
Solanum sp.				0.15520	1	Canopy
Solanum torvum				0.14630	1	Canopy
banlah dei suhut				0.13340	1	Canopy
daum bat leuh				0.13270	1	Canopy
kbuht				0.12740	1	Canopy
Tamarindus indica				0.12370	1	Canopy
Annona sp.				0.12050	1	Canopy
Amaranthus spinosus				0.11960	1	Understory
swai kteeh				0.11300	1	Canopy
voah preng				0.11230	1	Canopy
mreah preu				0.11230	1	Canopy
ampul prawk playee				0.09530	1	Understory
chplang awnlooung				0.09530	1	Understory
Lagenaria siceraria				0.09530	1	Understory
kwien kvahn				0.09530	1	Understory
momeeng kmoung				0.09530	1	Understory
momun				0.09530	1	Understory
ptee banlah				0.09530	1	Understory
smau momeeh				0.09530	1	Understory
tawmbok				0.09530	1	Understory
Argyreia obtecta				0.09530	1	Understory
trawsout loyn				0.09530	1	Understory
trop kmauich				0.09530	1	Understory
trup bai				0.09530	1	Understory
Holarrhea pubescens				0.09530	1	Understory
voah lep				0.09530	1	Understory

Appendix 6: Livelihoods and Land Use Survey, Khmer Version

ការសំភាសន៍ អំពីមុខរបរចិញ្ចឹមជីវតប្រចាំថ្ងៃ
ដើម្បី
ប្រៀបធៀបការប្រើប្រាស់ ដីព្រៃ ដីស្មៅ ដីទួល ដីស្រែ
នឹងបឹងនៅវាលក្រោម
សំរាប់រយៈ១ឆ្នាំ
ក្នុងភូមិរកា សង្កាត់ស្រយូវ ក្រុងស្ទឹងសែន ខេត្តកំពង់ធំ

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ថ្ងៃខែឆ្នាំ ៖

ឈ្មោះអ្នកសំភាសន៍ ៖

ឈ្មោះម្ចាស់ផ្ទះ ៖

ក្រុមលេខ ៖

ឈ្មោះអ្នកសំភាសន៍ ៖

ឈ្មោះអ្នកត្រូវសំភាសន៍៖

ភេទ៖ អាយុ៖

រយៈពេលបានរស់នៅភូមិរកា៖

មនុស្សប៉ុន្មានអ្នកស្នាក់នៅផ្ទះនេះ៖

សំណួរអំពីដីព្រៃវាលក្រោម

១. តើឆ្នាំនេះ មនិស្សដែលស្នាក់នៅក្នុងផ្ទះនេះ បានរករបស់អ្វីខ្លះសំរាប់ចិញ្ចឹមជីវិតប្រចាំថ្ងៃ នៅឯដីព្រៃវាលក្រោម?

១ក. តើរបស់ដែលអ្នករកបាននេះ ប្រសិនបើលក់ បានប្រាក់ចំនួនប៉ុន្មាន?

១ខ. បើប្រៀបធៀបឆ្នាំនេះទៅនឹង ៥ឆ្នាំមិន តើរបស់ដែលរកបាននៅឯដីព្រៃវាលក្រោម ខុសគ្នាដូចម្តេច? តើប្រសិនបើខុសគ្នា មូលហេតុអ្វី?

១គ. បើប្រៀបធៀបឆ្នាំនេះទៅនឹង ឆ្នាំដែលពិបាក តើរបស់ដែលរកបាននៅឯដីព្រៃវាល ក្រោមខុសគ្នាដូចម្តេច? តើប្រសិនបើខុសគ្នា មូលហេតុអ្វី?

សំណួរអំពីដីស្មៅវាលក្រោម

២. តើឆ្នាំនេះ មនិស្សដែលស្នាក់នៅក្នុងផ្ទះនេះ បានរករបស់អ្វីខ្លះសំរាប់ចិញ្ចឹមជីវិតប្រចាំថ្ងៃនៅឯដីស្មៅវាលក្រោម?

២ក. តើរបស់ដែលអ្នករកបាននេះ ប្រសិនបើលក់ បានប្រាក់ចំនួនប៉ុន្មាន?

២ខ. បើប្រៀបធៀបឆ្នាំនេះទៅនឹង ៥ឆ្នាំមិន តើរបស់ដែលរកបាននៅឯដីស្មៅវាលក្រោមខុសគ្នាដូចម្តេច? តើប្រសិនបើខុសគ្នា មូលហេតុអ្វី?

២គ. បើប្រៀបធៀបឆ្នាំនេះទៅនឹង ឆ្នាំដែលពិបាក តើរបស់ដែលរកបាននៅឯដីស្មៅវាលក្រោមខុសគ្នាដូចម្តេច? តើប្រសិនបើខុសគ្នា មូលហេតុអ្វី?

សំណួរអំពីដីទួលវាលក្រោម

៣. តើឆ្នាំនេះ មនិស្សដែលស្នាក់នៅក្នុងផ្ទះនេះ បានរករបស់អ្វីខ្លះសំរាប់ចិញ្ចឹមជិវិតប្រចាំថ្ងៃ នៅឯដីទួលវាលក្រោម?

៣ក. តើរបស់ដែលអ្នករកបាននេះ ប្រសិនបើលក់ បានប្រាក់ចំនួនប៉ុន្មាន?

៣ខ. បើប្រៀបធៀបឆ្នាំនេះទៅនឹង ៥ឆ្នាំមិន តើរបស់ដែលរកបាននៅឯដីទួលវាលក្រោម ខុសគ្នាដូចម្តេច? តើប្រសិនបើខុសគ្នា មូលហេតុអ្វី?

៣គ. បើប្រៀបធៀបឆ្នាំនេះទៅនឹង ឆ្នាំដែលពិបាក តើរបស់ដែលរកបាននៅឯដីទួលវាលក្រោមខុសគ្នាដូចម្តេច? តើប្រសិនបើខុសគ្នា មូលហេតុអ្វី?

សំណួរអំពីដីស្រែវាលក្រោម

៩. តើឆ្នាំនេះ មនិស្សដែលស្នាក់នៅក្នុងផ្ទះនេះ បានរករបស់អ្វីខ្លះសំរាប់ចិញ្ចឹមជិវិតប្រចាំថ្ងៃនៅឯដីស្រែវាលក្រោម?

៩ក. តើរបស់ដែលអ្នករកបាននេះ ប្រសិនបើលក់ បានប្រាក់ចំនួនប៉ុន្មាន?

៩ខ. បើប្រៀបធៀបឆ្នាំនេះទៅនឹង ៥ឆ្នាំមិន តើរបស់ដែលរកបាននៅឯដីស្រែវាលក្រោមខុសគ្នាដូចម្តេច? តើប្រសិនបើខុសគ្នា មូលហេតអ្វី?

៩គ. បើប្រៀបធៀបឆ្នាំនេះទៅនឹង ឆ្នាំដែលពិបាក តើរបស់ដែលរកបាននៅឯដីស្រែវាលក្រោមខុសគ្នាដូចម្តេច? តើប្រសិនបើខុសគ្នា មូលហេតអ្វី?

សំណួរអំពីដីបឹងថ្លុកនិងអូវាលក្រោម

៥. តើឆ្នាំនេះ មនិស្សដែលស្នាក់នៅក្នុងផ្ទះនេះ បានរករបស់អ្វីខ្លះសំរាប់ចិញ្ចឹមជិវិតប្រចាំថ្ងៃនៅឯដីបឹងថ្លុកឬអូវាលក្រោម?

៥ក. តើរបស់ដែលអ្នករកបាននេះ ប្រសិនបើលក់ បានប្រាក់ចំនួនប៉ុន្មាន?

៥ខ. បើប្រៀបធៀបឆ្នាំនេះទៅនឹង ៥ឆ្នាំមិន តើរបស់ដែលរកបាននៅឯដីបឹងថ្លុកឬអូវាលក្រោមខុសគ្នាដូចម្តេច? តើប្រសិនបើខុសគ្នា មូលហេតុអ្វី?

៥គ. បើប្រៀបធៀបឆ្នាំនេះទៅនឹង ឆ្នាំដែលពិបាក តើរបស់ដែលរកបាននៅឯដីបឹងថ្លុកឬអូវាលក្រោមខុសគ្នាដូចម្តេច? តើប្រសិនបើខុសគ្នា មូលហេតុអ្វី?

សំណួរផ្សេងៗ

៦.) តើឆ្នាំនេះ មនុស្សដែលស្នាក់នៅផ្ទះនេះ បានដាំដើមឈើ ឬ រុក្ខជាតិផ្សេងទៀន ក្រោមភូមិ ឬនៅវាលក្រោមទេ?

៧.) បើបានដាំ តើដាំដើមអ្វី? ដាំប៉ុន្មានដើម? ដាំនៅទីណា?

៨.) តើឆ្នាំនេះ មនុស្សដែលស្នាក់នៅផ្ទះនេះ បានហែកដីក្រៅភូមិ ឬ នៅវាលក្រោម ដែឬទេ?

៩.) បើបានហែកដី តើធ្វើទំហំប៉ុនណា? ធ្វើនៅទីណា?

១០.) តើឆ្នាំនេះ មនុស្សដែលស្នាក់នៅផ្ទះនេះ បានកាប់ដីដើម្បីលុបបឹងថ្លុក ឬ ជីកបឹងថ្លុកថ្មី ក្រៅភូមិ ឬ នៅវាលក្រោមទេ?

១១.) បើបានកាប់ដីដើម្បីលុបបឹងថ្លុក កាប់ទំហំប៉ុនណា? កាប់នៅទីណា? បើបានជីកបឹងថ្លុកថ្មី ជីកទំហំប៉ុនណា? ជីកនៅទីណា?

Appendix 7: Livelihoods and Land Use Survey, English Translation

Appendix 7: Livelihoods and Land Use Survey, English Translation

Survey Title

Livelihood interview in Order to Compare the use of Shrubland, Grassland, Hillocks, Rice fields and Waterbodies Over the Last Year in Roka Village, Sangkat Srayov, Steung Sen District, Kampong Thom Province

General Information Questions

Date of interview

Name of interviewer

Name of the owner of the house

Village group number

Name of person being interviewed

Gender of person being interviewed

Age of person being interviewed

Amount of time interviewee has lived in Roka Village

Total number of people staying in the house

Questions Regarding Land Use and Change Over Time

LULC Class Shrubland

1a. This year, people who live in this house collected which natural products or performed which livelihood activities in the shrubland on the flood plain?

1b. If these products were sold, how much money were they sold for?

1c. If you compare this year with 5 years ago, how are the products you collected or activities you performed in the shrubland on the flood plain different?

1d. If you compare this year with “difficult years”, how are the products you collected or activities you performed in the shrubland on the flood plain different?

LULC Class Grassland

2a. This year, people who live in this house collected which natural products or performed which livelihood activities in the grasslands on the flood plain?

2b. If these products were sold, how much money were they sold for?

2c. If you compare this year with 5 years ago, how are the products you collected or activities you performed in the grasslands on the flood plain different?

2d. If you compare this year with “difficult years”, how are the products you collected or activities you performed in the grasslands on the flood plain different?

LULC Class Hillock

3a. This year, people who live in this house collected which natural products or performed which livelihood activities on the hillocks on the flood plain?

3b. If these products were sold, how much money were they sold for?

3c. If you compare this year with 5 years ago, how are the products you collected or activities you performed on the hillocks on the flood plain different?

3d. If you compare this year with “difficult years”, how are the products you collected or activities you performed on the hillocks on the flood plain different?

LULC Class Ricefield

4a. This year, people who live in this house collected which natural products or performed which livelihood activities in the rice fields on the flood plain?

4b. If these products were sold, how much money were they sold for?

4c. If you compare this year with 5 years ago, how are the products you collected or activities you performed in the rice fields on the flood plain different?

4d. If you compare this year with “difficult years”, how are the products you collected or activities you performed in the rice fields on the flood plain different?

LULC Class Waterbody

5a. This year, people who live in this house collected which natural products or performed which livelihood activities in the lakes, ponds and rivers on the flood plain?

5b. If these products were sold, how much money were they sold for?

5c. If you compare this year with 5 years ago, how are the products you collected or activities you performed i in the lakes, ponds and rivers on the flood plain different?

5d. If you compare this year with “difficult years”, how are the products you collected or activities you performed i in the lakes, ponds and rivers on the flood plain different?

Questions Regarding Landscape Modification

6. This year, have people who live in this house planted trees or other plants outside of the village or on the floodplain?

7. If any trees or plants were planted, which kinds were planted? How many were planted? Where were they planted?

8. This year, did people who live in this house clear land for new rice fields outside the village or on the floodplain?

9. If land was cleared, what is the area of the cleared fields? Where are they?

10. This year, did people who live in this house fill in any existing ponds or dig any new ponds outside of the village or on the floodplain?

11. If any ponds were filled, how large was the area filled? Where was it? If any new ponds were dug, how large are they? Where are they located?

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Autobiographical Statement

Andrew S. Roberts received his BS degree in Sustainable Agriculture from the University of Maine in 1994. After spending subsequent years as a research and curatorial assistant at the New York Botanical Garden, he and his wife joined the Peace Corps. They served together in Tanzania, living in a rural village from 1999-2001. As an agricultural extension agent, Andrew's work revolved around educating farmers about organic agriculture, tree propagation and agroforestry techniques. Upon their return to the US, Andrew joined the PhD program in Biology at the City University of New York. He now lives on Maryland's Eastern Shore with his wife and 2 children.