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Forests and Farmers: A Landscape Approach to Settlement Pattern Analysis in the Bolivian Amazon

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FORESTS AND FARMERS: A LANDSCAPE APPROACH TO SETTLEMENT PATTERN ANALYSIS IN THE BOLIVIAN AMAZON

by

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ABSTRACT

The Llanos de Mojos of the Bolivian Amazon is a domesticated landscape with a long history of management by pre-Columbian communities. This project uses a landscape approach to interpret the settlement patterns of pre-Columbian raised field farmers in west central Mojos. The pre-Columbian landscape was reconstructed by mapping the distribution of three types of landscape features: forest islands, raised agricultural fields and water systems (rivers, streams & wetlands). Previous research has identified four types of patterned clustering or 'constellations' of these landscape features in west central Mojos. These constellations and the immediate area of the landscape that surrounds them afforded Mojos farmers a specific set of tasks or activities related to harnessing resources from the landscape. The mapping of landscape features and their associated tasks provides insight into the organization of the communities that constructed and managed them. It was found that the landscape of west central Mojos is organized into two distinct regional patterns. In the northern part of the region, evidence of large farming communities is dispersed along the banks of permanent rivers with networks of landscape features extending off into remote areas of the savanna. In the southern part of the region, evidence of large farming communities is clustered closer together in remote areas of the savanna with networks of landscape features extending back towards the permanent rivers. The two regions are melded together by a transitional zone that implies interaction between the regions rather than a distinct separation.

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CHAPTER 1: INTRODUCTION

Amazonia provides some of the most valuable ecosystem services on earth (Costanza et all 1997; Costanza et all 2014). The region contains more than 40,000 species within approx. 12% of the worlds global forest coverage and is a hotspot for linguistic diversity given the high number of endemic language groups (FAO 2015; Gorenflo et al. 2012:8034; IPBES 2019a:46). In an age of increasing awareness of global climate change, Amazonia represents a region with an abundance of biological and cultural resources. As a result, modern day land management practices in Amazonia are economically and politically charged with regular discussion in popular media (Borunda 2019; Krauss 2019; Sullivan 2019; Walt 2019) as well as international politics (Gilley & Kinsella 2015). It is increasingly more important for policy makers to properly evaluate the costs and tradeoffs that come with prioritizing different ecosystem services or land management practices (Brauman 2007:85). Essential to evaluating different ecosystems and their services is an understanding of how human society is not separate from nature and the services that it provides. It is instead embedded within nature and taking part in co-producing nature and the ecosystem services that benefit humans (Costanza et al. 2014).

Historically, conservation efforts have begun with an attempt to re-create an ecosystem that is believed to be undisturbed by human activity. This is a view in which an ecosystem can be wound back in time to a stable state that pre-dates human presence in the landscape. This perspective allows for the imagining of an 'ecological baseline' that becomes the goal of conservation efforts (Arcese & Sinclair 1997). Originally, Amazonia fit well into this line of reasoning. In its earliest descriptions by scientists, the Amazon was presented as a 'pristine' ecosystem lacking any significant impact from human populations (Bush and Silman 2007).

Human populations were believed to be limited to small dispersed groups as a result of natural selective processes. When archaeologists began to provide evidence of large populations within the region, they were still thought to be restricted to marginal areas along the main river networks. The environment was considered too harsh to support large populations of humans outside these marginal areas (Meggers 1971).

Contrary to this view, a large body of archaeological and ethnobotanical evidence now indicates that the Amazon basin supported large populations of pre-Columbian communities who actively managed the landscape for natural resources while raising local biodiversity (Erickson 2000; Heckenberger et al. 2003; Erickson 2006; Levis et al. 2017; Mann 2005; Walker 2018). Far from being considered pristine, the Amazon "is actually a hugely important centre of domesticated nature, contributing significantly to the global agricultural economy" (IPBES 2019b:56). Strong correlations have also been recognized between regions of high biological and high linguistic diversity (Gorenflo et al. 2012). The presence of large human populations in the history of the Amazon basin implies that socio-historical contexts should be taken into consideration when setting an ecological baseline for conservation (Heckenberger et al. 2007:199). Pre-Columbian communities managed the landscape and they encountered a variety of socio-economic and political factors while doing so (Walker 2018).

Modern land management choices regarding issues like deforestation and clearing land for farming are often related to a region's perceived resilience to past human disturbance (Lombardo et al. 2011:503). Misrepresenting the past relationships between society and nature comes with the risk of supporting modern policy that over-exploits natural resources and results in further environmental degradation (Meggers 2001; Bush and Silman 2007). Underrepresenting the relationships that past societies had with nature has made it easier to

ignore the voices of indigenous groups who have their own methods of managing the landscape (Heckenberger et al. 2007). The question is not just how large past human populations were or to what extent they disturbed the environment. More important is considering the alternative ways that past people went about relating to and interacting with the landscape itself (Walker 2018). South American anthropologists recognize that South Americans both in the past and today developed complex relationships with the environment and other living things (Walker 2012:310; Descola 2016; Kohn 2013).

Landscape archaeologists are well positioned to approach Amazonia as a cultural as well as natural landscape that is the product of historical human social processes (Heckenberger et al 2007). Landscape is a popular term that has been used with a variety of meanings across different disciplines and throughout its historical use in South America (Walker 2012). Such vague nomenclature can be problematic, and it is important for landscape archaeologists to more clearly define terms such as this. This project defines a landscape as an experience. Through the act of dwelling, humans experience landscapes that they create and maintain. A place can be characterized by the experiences it affords and the types of activities or tasks that inhabitants of that place engage in (Ingold 1993:154, 156).

If a landscape is defined here as an experience, then what is a landscape feature? Landscape features do not make up a complete landscape but provide a structure to its organization. Landscape features typically include settlements, agricultural fields, roads or pathways, and water systems (Wilkinson 2003:44). Landscape features in this project are assumed to provide inhabitants in the region a variety of tasks related to those features. A landscape feature like a seasonal stream or canal provides the opportunity for trade or travel

along the water network. Landscape features in this sense contribute to a patterned experience that makes up the landscape.

The landscape with its defining features then is not something that can be easily measured and mapped given the variety of experiences and perspectives that any region affords its inhabitants. One approach to measuring or mapping the landscape is to think about the variety of activities or tasks that an individual may take part in while experiencing a particular part of the landscape. Ingold (1993: 158) proposes the use of a 'taskscape' to represent the interlocking nature of different tasks linked to the creation and maintenance of a landscape. A landscape feature like an agricultural field can afford a variety of tasks such as the organization of a work party to construct the fields or an individual farmer visiting the fields periodically to pull weeds. Hunters may visit agricultural fields to look for game animals. Several times a year a field may be visited to clear its canals or set a seasonal fire. When viewed as events in a sequence, these tasks have a social temporality to them that links each task to the previous task and the next task. One task is never isolated from the others or from the landscape that is experienced by the community dwelling there. Through its continued presence within the landscape, a feature like an agricultural field continues to afford a variety of tasks for farmers to take part in over time. Tasks may be individually listed but are intrinsically linked to larger groups of tasks related to the landscape and to the encompassing social networks that surround daily life. This understanding of the landscape as a patterned social experience is essential to the landscape approach used here.

A landscape approach has been referred to as 'siteless archaeology' (Dunnell and Dancey 1983; Dunnell 1992) as well as 'distribution archaeology' (Ebert et al. 1987). Mainstream spatial analysis on 'settlement patterns' revolve around the distribution of 'sites' representing

important places of extended habitation (Kowalewski 2008:227). These important places are identified by an increase in the accessibility of material remains, often found through survey (Kowalewski 2008:227). A site is generally believed to represent a single unit of settlement (King 1978). Site-based surveys emphasize activity in and around specific sites. However, human activities in the past occurred at regional scales that included inter-site portions of the landscape that are often overlooked (Dunnell and Dancey 1983; Ebert 1992).

A siteless approach is one in which individual artifacts rather than sites act as the empirical units of observation. The material record is not a collection of site and non-site locations but rather a "continuous distribution of artifacts" that can be aggregated together in interpretively meaningful ways (Dunnell 1992:34). At this scale the most basic unit is the individual artifact rather than the bounded site and this unit can be built up with other artifacts of related deposition into larger interpretive units (Dunnell 1992:34). The area of study becomes the chosen focal point at which the archaeologist can make reasonable interpretations of the material record and the past historical processes that took part in its creation. This ability to shift scales provides a view of Amazonia that looks beyond a cluster of trees or a single forest island to a larger landscape that is representative of a more complex and interdependent relationship between humans and their environment. This approach does not ignore the fact that settlements and agricultural fields are mapped much like sites. Rather a landscape approach has the advantage of moving beyond the site as the focus of investigation and instead emphasizing how people moved between sites and went about interacting with their environment in patterned ways.

The Llanos de Moxos (or Mojos) of the Bolivian Amazon has been described as an example of a domesticated or anthropogenic landscape (Erickson 2006b; Erickson 2008:156;

Erickson & Walker 2009) and provides an excellent case study for a landscape approach to interpreting past human-environment interactions at the community level. In the floodplains of Mojos, pre-Columbian communities constructed a variety of earthworks that are still visible in the landscape through aerial survey (Erickson 2000; Erickson 2008:165; Erickson & Balée 2006:189). Though difficult to see from the ground, many of these features are visible from satellite imagery making them accessible for mapping and analysis as features in the landscape. The seasonality of the landscape also aids in the identification of forest island occupation sites. These discrete patches of forest are located on areas of high ground and stand out in contrast to the surrounding savanna grasses. Forest islands are generally small to irregular in shape. They range from less than one hectare in size to several hundred hectares in size and are located on areas of elevated high ground with reduced exposure to inundation (Denevan 1966; Langstroth 1996). A majority of surveyed forest islands in west Central Mojos contained pre-Columbian ceramics on their surfaces with no continuous collections of finds extending into the savannas (Walker 1997, Walker 2018:71). This makes the distribution of forest islands in west central Mojos an excellent proxy for the distribution of pre-Columbian settlements within the landscape.

The purpose of this project was to use a landscape approach to interpret settlement patterns of pre-Columbian raised field farmers in west central Mojos. The pre-Columbian landscape was reconstructed by mapping the distribution of three types of landscape features: forest islands, raised agricultural fields and water systems (rivers, streams & wetlands). From the intersection of these three features, maps of Landscape Units were created that represent the different combinations of tasks afforded by the intersection of different landscape features in any given part of the landscape. The primary objective was the creation of four maps, one map for each of the four types of Landscape Units as identified by Walker (2018:100-102).

Landscape Units

As part of a landscape approach areas of the landscape are analyzed based on the variety of tasks that members of a community carry out to construct and maintain patterned groups of landscape features (Walker 2018). For example, areas with numerous raised fields as well as permanent rivers afforded inhabitants a wide range of tasks relating to farming on raised fields as well as trade and transportation along permanent rivers. While carrying out these tasks, members of a community moved between forest islands and raised fields. However, this experience included larger portions of the landscape than just the platforms of raised fields and the interiors forest islands. Areas of the landscape with fewer or no agricultural fields and no permanent rivers may be associated with other tasks such as setting fires on the savanna, hunting game or visiting seasonal fishing holes. Landscape Units represent ways in which the permanent modifications to the landscape had the potential to pattern the daily activities of the communities who dwelled there.

There is no ethnographic analogy from which to interpret the distances at which a set of landscape features become more or less associated with one another. For this project, a series of suitability maps were created for each of the four Landscape Units described below. These suitability maps represent the proximity of each portion of the landscape to a given landscape feature. Suitability maps are created by buffering each of the vector-based datasets and assigning a ranking value to each of the buffered regions identified. All vector-based maps were converted to 500m x 500m rasters for combination into Landscape Suitability Maps. By combining multiple suitability maps into a single map, an interpretation could be made as to the distribution of any given Landscape Unit across the entire landscape. All maps of Landscape Units were created and analyzed as 500m x 500m rasters so they could be combined together to

analyze their distribution and overlap with one another across the landscape. These 500m cells are by no means meant to represent the mobility limits of pre-Columbian peoples. Movement is not restricted within cells but rather each cell is meant to represent a patterned set of activities available to inhabitants passing through that part of the landscape. In this sense the landscape can be experienced through a raster map of the landscape by allowing the viewer to understand and imagine the different activities that potentially exist within each cell and how those activities are distributed across the region.

Neighborhood Landscape Units

These Landscape Units are defined as any area of the landscape within close proximity of a raised field Neighborhood. They represent locations where farmers would be more likely to interact with one another while carrying out tasks related to constructing and tending raised field platforms. They are constructed from a vector-based map of all raised field Neighborhoods in Mojos. Raised field Neighborhoods are represented by groups of raised field platforms close enough in proximity to prevent new fields being built between existing fields (Walker 2018:100). The farmers using these platforms would have been more likely to interact and cooperate in order to negotiate the construction of new fields in such close proximity. Isolated fields more than 40m from the nearest raised field are very rare (Lee 2017). Individual raised field platforms could have been constructed by community work parties (Walker 2001) and the size of an oriented group is comparable to the carrying requirements of the work party needed to construct a single platform within the group (Walker 2008). A Neighborhood in this sense represents a level of organization one step above that of the oriented groups and raised field platforms. A Neighborhood's fields were not all constructed in one event or planned sequence of

events but share some level of cooperation among the same community of individuals investing in the landscape.

"Communities that built and maintained Neighborhoods were obviously concerned with the construction, maintenance, and farming tasks associated with the field platforms, but also with fire management… Community ritual on and near Neighborhoods of raised fields must be considered in light of the dense scatters of painted ceramics found near the field Neighborhoods in the San Juan Landscape" of west central Mojos (Walker 2018:101-102).

Buffer Landscape Units

Buffer Landscape Units are defined as any area of the landscape that lacks a strong association with either raised field Neighborhoods or forest island landscape features. These Landscape Units are interpreted from a combined landscape suitability map representing each portion of the landscape rated on its combined distance to the nearest forest island as well as raised field Neighborhoods. "The buffer landscapes… are the places where the fewest community tasks are evidenced. Although hunting could still be important, and fishing is possible, the remoteness of these places makes it most likely that they are used as places to escape from unwanted interaction or to reduce conflict between communities…" (Walker 2018:102).

Archipelago Landscape Units

In west central Mojos, seasonal streams run from the permanent flowing rivers out into the more remote areas of the savanna. Walker (2018) reports groups of small forest islands with associated raised field Neighborhoods strung along these streams both close to the permanent

rivers as well as further out in the savanna. Archipelago Landscape Units are defined here as any area of the landscape with strong associations to seasonal streams, small raised field Neighborhoods and small forest islands (<=0.8ha). These Landscape Units are interpreted from a combined landscape suitability map representing each portion of the landscape rated on its combined distance to the nearest seasonal stream, small forest island, and small raised field Neighborhood.

"Archipelago communities were less concerned with the farming and construction of raised fields and perhaps more with transportation either in a positive sense (connecting to a larger riverine transportation system) or in a negative sense (avoiding contact with people along the navigable rivers). Fishing could be seasonally important, as some populations of fish head out into the savanna during the wet season, to return in the fall (Walker 2018:102)."

Agropolis Landscape Units

In west central Mojos strong associations have been noted between large forest islands and large Neighborhoods containing above average numbers of raised field platforms (Walker 2018). The Agropolis Landscape Unit is defined as any area of the landscape with strong associations to large forest islands, large Neighborhoods and one of the permanent flowing rivers or major wetland networks. These Landscape Units are interpreted from a combined landscape suitability map representing each portion of the landscape rated on a combined distance to these three landscape features.

"Agropolis communities utilize the broadest spectrum of potential tasks, including all the tasks associated with field Neighborhoods and adding the tasks associated with large occupations, including transportation through the large, navigable rivers. If community history

and ritual are important, ring ditches are larger, denser populations suggest that Agropolis landscapes might be where these tasks took place. And many fishing tasks are associated with oxbow lakes along the rivers (Walker 2018:102)." The Agropolis Landscape Units represent areas of the landscape where the greatest variety of tasks intersect together in one location on the landscape.

A landscape approach to west central Mojos has the potential of clarifying how different parts of the landscape were incorporated together into a more complex seasonal subsistence system. It was found that the landscape of west central Mojos is organized into two distinct regional patterns. In the northern part of the region, evidence of large farming communities is dispersed along the banks of permanent rivers with networks of landscape features extending off into remote areas of the savanna. In the southern part of the region, evidence for large farming communities is clustered closer together in remote areas of the savanna with networks of landscape features extending back towards the permanent rivers. The two regions are melded together by a transitional zone that implies a type of interaction between the regions rather than a distinct separation. Future research in west central Mojos can examine how this transitional zone overlaps with other subsistence activities such as fishing and how they relate to the placement of agricultural earthworks in west central Mojos.

CHAPTER 2: LLANOS DE MOJOS

Mojos is easy to distinguish from the rest of Amazonia in most regional maps and satellite imagery (Figure 1). The nearly 100,000 km^2 of seasonally inundated savannas that define Mojos stand out in stark contrast to the approx. 5.2 million km^2 of tropical rainforest that surround them (Denevan 1966:6; Aragão et al. 2014:914). Although Mojos can easily be identified by the large expanse of savanna, it contains a mosaic of forest and wetland ecosystems as well as a variety of pre-Columbian landscape features (Figure 2; Denevan 1966; Erickson 1995; Erickson 2000).

While describing Mojos as a region can begin with its environmental characteristics such as elevation, annual rainfall, and vegetation cover; the landscape is best understood as a domesticated one that is a palimpsest record of the historical relationships between human society and nature (Erickson 2000:187; Erickson 2006). Fixed within the vegetation patterns described below are complex interactions not just between organisms and their environment but also between human communities and the landscapes they dwelled in (Erickson 2000:187). The Mojos landscape can be divided into three categories based on the vegetation patterns visible from satellite imagery: savannas or pampas, gallery or flooded forests, and forest islands. Transition from one type of vegetation to another in some cases forms a gradient while others have a much sharper transition. Each of these patterns is related to the strong seasonality of the landscape and a history of human activities that took part in producing the landscape.

Seasonal Flooding

Each year, seasonal rains flood Mojos savannas and some of the rivers and streams overflow their banks. A variable amount of savanna floods each season with water rising into the forested high grounds in periods of most extreme flooding (Denevan 1966; Walker 2008:927; Erickson 2000). Water recedes with the onset of the dry season and quickly becomes a scarce resource on the open savanna. Seasonal change is a main characteristic of the landscape and all life in Mojos experiences seasonality in some way.

Mojos as a whole is a large basin with elevation rising both to the southwest near the base of the Andes as well as the north and northeast towards the rock outcrops of the Precambrian and Brazilian Shield regions. Across the basin, elevation is very flat and changes less than 20 cm per km (Denevan 1966). The region is divided in half by the Mamoré river which cuts across landscape south to north as it makes its way to the Rio Madeira, one of the main tributaries of the Amazon. Tributaries of the Mamoré meander across western Mojos from southwest to northeast following the abandoned paleochannels cut by the Beni river as it altered its course across the landscape over time (Denevan 1966; Langstroth 2011:185).

During the wet season, waters downstream in the Rio Madeira begin to backup and the waters of the Mamore and its tributaries can appear to flow backwards as floodwaters begin to fill the region. This ‘water from below’ has the potential to overflow the banks of the rivers and flood large portions of the landscape, however, ‘water from above’ also contributes to flooding in the savanna as local rainwater collects in the low lying areas (Denevan 1966, Walker 2008). Mojos soils contain an impermeable horizon of packed stone and clay that allows water to pool in the lowest lying areas rather than drain away (Denevan 1966; Lombardo et al. 2011). In such a large flat landscape, just a few centimeters change in elevation can alter local flood patterns

and result in different types of plant and animal species as well as human activities (Denevan 1966; Langstroth 1996:18).

Savanna

The Mojos savanna is a grassland or 'pampa' that may be inundated for more than five months a year depending on elevation and local weather patterns. Regions with increased exposure to flooding may be dominated by a variety of grasses and sedges from 12 different genera of plants (Denevan 1966:15; Langstroth 1996; Langstroth 2011). In the dry season water is scarce on the open savanna. Today cattle ranchers use heavy machinery to excavate large pits that can be used as watering holes for cattle. The savannas are the defining feature of Mojos for geographers though they are not continuous across its entire extent (Langstroth 1996:17). A variety of forest types surround the region and cut across the interior. Seasonally flooded forests straddle the banks of the permanent rivers and lakes. Areas of high ground with the least exposure to flooding contain forest islands or *islas* that are scattered in small patches across the savanna and amidst the gallery forests (Figure 3). Forest islands represent the most habitable parts of the landscape amidst the seasonally inundated grasslands and are discussed more thoroughly below. Known as *llanos* to geographers, Mojos is one of several llanos found in the Amazon basin (Langstroth 1996:6).

The origins of savanna ecosystems in the tropics are debated by archaeologists, ecologists, and other academics. Carl Sauer moved beyond the idea of climate as a primary cause of modern grassland expansion and championed anthropogenic fire as an alternative cause to climate (Sauer 1950:20). He noted that locations with similar climates do not always result in a grassland ecosystem. Rather, grasslands are found in areas that have a combination of a climate

marked by seasonal dry periods as well as a flat topography and seasonal fires. These flat dry conditions are favorable to the spread of fire. Since climate alone does not produce savanna ecosystems, fire should be considered as a primary force in their origins and persistence on the landscape (Sauer 1950; Sauer 1952:15-18).

Fire is found in all savanna ecosystems in South America, Africa, and Australia and it can be the determining factor as to whether or not a savanna or forest persists in an area as the climate changes (Staver et al 2011:231; Noss 2013:194). It has been proposed that savannas represent an alternative stable state to a forest in the same climate (Staver et al 2011:231). This means that given the same conditions, trees may or may not grow based on the presence of fire in the ecosystem. Fire as a disturbance also has a feedback effect with savanna ecosystems. During periods of increased dryness fires become more common and savannas begin to spread. As climate changes and moisture increases, savannas can persist in areas that would support forest by the continued presence of seasonal fires (Noss 2013:194). Naturally occurring fires are most commonly credited to lightning strikes during seasonal dry periods that coincide with increased thunderstorm activity. These seasonal storms peak in the tropics during the transition from the wet to dry season and ignite fuel loads of slowly decaying grasses that developed all year. Seasonal winds can push fires into established forest boundaries, destroying forests and expanding the extent of the savanna. The seasonal timing of these fires result in reduced tree growth compared to fires set by humans. Anthropogenic fires are patterned and generally set earlier in the year than naturally occurring lightning strikes. Less intense fires set earlier in the season are less effective at killing young trees. As a result, savannas managed by anthropogenic fire will see increased tree growth compared to those with fires set naturally by lightning strikes (Bond & Parr 2010: 2398-2399; Cardoso et al. 2008; Pyne 1998). Rather than emphasizing

origins of these ecosystems, it is becoming increasingly more important to understand how these ecosystems respond to transitions between natural fires and anthropogenic fires (Bond & Parr 2010:2399).

Sauer's argument relied heavily on his belief that humans had been operating in the western hemisphere for much longer periods of time than was recognized by contemporary science. More recent evidence has shown that large expanses of savanna did exist in the early Miocene, millions of years ago, indicating that savannas can proliferate through other factors than human disturbance such as the introduction of large herbivores into an ecosystem (Noss 2013:194). Setting aside intentionality and distant origins, fire still plays a critical role in the maintenance of savanna ecosystems, especially in the Amazon (Erickson 2008; Langstroth 1996). Erickson (2008) notes the presence of raised agricultural fields deep within modern forests. Constructing these fields would have required an initial clearing of forests and the regular use of fires to maintain a farmable landscape. After abandonment, forests were able to regrow over previously farmed lands (Erickson 2008:172).

Charcoal and pollen records from lake sediments from the Bolivian lowlands indicate a period of increased fire use that coincided with the introduction of of maize pollen. Large increases in charcoal in the lake sediments likely originated from large scale fires used to clear forests for the construction of raised fields. As fire use increased, arboreal pollen from savanna trees was greatly reduced in the lake sediments indicating that fire was being used to prevent the regrowth of trees on the savanna (Whitney et al. 2014:24). However, Langstroth (2011:189) argues that pre-Columbian earthworks and anthropogenic fires have not significantly altered the species makeup or diversity within the Mojos and the landscape is representative of an ecosystem that has been developing since long before the arrival of humans.

At this point the discussion must move beyond whether or not humans created the first savannas but rather to what extent they were involved in a more synergistic relationship with fire, the climate, and the spread and maintenance of savanna ecosystems (Rull et al. 2015). Mojos is important to this discussion given that savanna vegetation is its defining characteristic (Langstroth 1996), savanna ecosystems have persisted in the Bolivian lowlands for at least the past 50,000 years (Furley & Metcalfe 2007:635; Burbridge et al. 2004), and the landscape has a long history of management with fire both by pre-Columbian inhabitants (Erickson 2008) and by modern cattle ranchers (Denevan 1966). Throughout the Amazon basin small patches of savanna are generally found scattered in a mosaic amidst surrounding forests; some are likely savannas from past times when the climate was much drier (Rull et al. 2015), others transformed by the burning and settlement activities of pre-Columbian people (Erickson 2008:162; Erickson and Balée 2006). In Mojos, the difference is that the savanna is the dominant topography. Savanna is the primary backdrop to the landscape with forest cover restricted to smaller patches in open savanna or the seasonally flooded banks of permanent rivers and lakes. In this project, savanna vegetation is not mapped directly by the archaeologist or volunteer. Rather it is what is left behind after the satellite imagery is searched and marked for all forests, rivers, fields, and other discrete landscape features.

Gallery Forests

Lining the lower banks of the river levees are gallery forests which are flooded for many months each year (Walker 2004). These forests are distinct from forest islands or *islas* that are located on more elevated and better drained locations. Gallery forests are known for containing more dense concentrations of diverse and economically viable trees compared to forest islands

(Denevan 1966). Early explorers identified more than eighty species of trees with economic value (Block 1994). It is likely that indigenous groups selected economically useful species and planted and protected them from competition with other plants and animals (Erickson 2010). The high abundance of economically useful species of trees in the gallery forests near the Iruyañez river in west central Mojos could be evidence of a domesticated landscape (Whitney et al. 2014).

Forest Islands and Levees

The forested high ground of Mojos is found in scattered islands or *islas* both along the major river networks as well as scattered about the open savanna. These forest islands occupy elevated areas with sandy and better aerated soils that can support denser forests than those in the pampas (Denevan 1966). There are several possible origins for the forest islands in west central Mojos.

Many forests are the remains of larger levees that fragmented during the changing course of the rivers (Denevan 1966; Langstroth 1996). Troll (1936) cited by Langstroth (1996) noted several connections between different forest islands with similar tree species and the distribution of ant colonies. Mounding insects such as termites and ants have the potential to create or expand existing islands by providing an initial raised surface for trees to colonize. The addition of more trees allows for the collection of more sediments around the mound which in turns leads to the establishment of even more trees in an outward expansion of the *isla*. Troll also noted the similarities between ant mound construction and human mound construction suggesting the landscape provided a proxy for ancient inhabitants to follow (Langstroth 1996:21-23).

Humans can create forest islands in Mojos by suppressing fire and creating raised surfaces that promote tree growth (Langstroth 1996:27). Earth can be mounded slowly over time

as a byproduct of human occupation. Mounds constructed in a single event are often accompanied by a nearby borrow pit from which the earth was excavated. Some forest islands have been found growing atop abandoned agricultural fields (Erickson 1995; Langstroth 1996). This kind of evidence demonstrates the strong associations between forest islands and past human activities in Mojos.

According to Langstroth (1996) these factors cannot individually explain the existence of most forest islands in their current locations. Each forest island is subject to a unique set of interacting factors that should be considered in their own context. A problem of equifinality arises as forest islands ultimately represent elevated surfaces and there are several mechanisms for creating these elevated surfaces in the landscape.

While the origins of a particular forest island may be difficult to identify, archaeological surveys demonstrate more thoroughly how forest islands in Mojos have strong correlations with human occupation. Archaeological surveys of west central Mojos forest islands began in 1997. Evidence of human occupation was noted through the presence of ceramics, burned earth, and/or dark soils Walker 1999; Walker 2004). To date, 55 individual forest islands have been ground surveyed for surface collections. Of the surveyed islands, text excavations were carried out on 24 islands, and of those islands large excavations were carried out on 6 islands. Of the 55 surveyed forest islands, 78% contained ceramics either in surface finds or excavations. Of the surveyed forest islands, %91 contained either ceramics, burned earth, dark soil, or some combination of the three. (Walker 1997; Walker & Bocchietti 2007; Walker & Bocchietti 2008; Walker et al. 2011; Walker et al. 2012; Walker et al. 2013; Walker et al. 2018; Walker et al. 2019). Given the high occurrence of evidence of human occupation on forest islands, and the equifinality problem regarding forest island creation, it would be more difficult to prove that an

island was not at one point inhabited by humans than to prove that it was. While human occupations are more closely related to the forest islands than the savanna, only some of the smallest forest islands have ceramics distributed continuously across their surface. Most forest islands have ceramics concentrated into smaller areas of occupation within the forest boundary (Walker 2018).

Capriles et al. (2019) identified burials within forest islands in southern Mojos dating between 4,000 and 10,600 years ago making it possible that they were the first landscape features created by pre-Columbian peoples in southwestern Amazonia (Capriles et al. 2019:6). These locations have a strong correlation with permanent wetlands and seasonality given the presence of shell middens. By altering the landscape near wetland resources, the inhabitants may have been able to enhance those resources over time (Capriles et al. 2019:7). Forest islands in Mojos are an excellent example of a feature that is a blend of both human and natural influences.

Pre-Columbian Peoples of Mojos

In the early 16th century, Spanish explorers near Paraguay encountered silver and other ornamental trade items that were likely of Peruvian origin and had passed through Mojos via long distance trade networks. Mistaking Mojos as the source of these precious objects, the Spanish perpetuated a story of the 'Gran Mojo' as a wealthy kingdom at the center of the Mojo plains (Metraux 1943:3; Block 1994:16). Many early expeditions to Mojos failed. Those that did, reported dense settlements of pre-Columbian Indians who foraged as well as farmed the landscape. Jesuit Jronimo de Andion visited the Mojos savanna in 1595 and reported hospitable greetings from a settlement who "supplied them with food and forage until floodwaters covered their gardens and the native pastures" (Block 1994:19). The Holguin expedition of 1617

provided several first-hand accounts of large dense settlements within visible distance of one another, each with several hundred residential houses, kitchen sheds, drinking houses, temples or religious structures, and extensive networks of agricultural fields crossed by raised earthen causeways (Denevan 1966:98; Metraux 1943:4; Block 1994:19). In the early 17th century, European interests in Mojos shifted to raiding the region for slaves. This outside disturbance combined with the introduction of European diseases in the population contributed to the significant depopulation of the region (Denevan 1966; Block 1994:20).

The best historical information on the people of Mojos comes from the accounts of Jesuit missionaries working in the region between 1668 and 1768 (Denevan 1966:30,31; Block 1994). Through giving valuable gifts such as cattle and iron tools, the Jesuits exposed local communities to Christianity and convinced them to reorganize their settlements into large mission towns near the navigable rivers. In these towns, the missionaries attempted to replace native cultures with their own, introducing new skills such as textile production and cattle ranching. Their first-hand accounts provide some of the only descriptions of pre-Columbian peoples in Mojos before they were drastically changed by European contact (Metraux 1943:4; Denevan 1966:31).

Jesuit accounts underscore the high linguistic diversity among Mojos communities despite having relatively similar cultural practices. All groups in the region developed surplus agriculture, took part in trade & warfare, had political and religious specialists and an established belief system (Block 1994:22). More than 30 different tribes belonging to at last 10 language groups were identified within Mojos. Based on a hierarchy of population size and political power, the Jesuits identified six major tribes including the Moxo, Baure, Cayuvava, Itonama, Movima and Canchana (Denevan 1966:40; Block 1994:16). This project analyzed the landscape

of west central Mojos (Figure 4), defined below, which corresponds loosely to the Cayuvava and Movima peoples whose proposed territorial boundaries are described by Denevan (1966). These two groups overlap with the known distribution of large raised field platforms also discussed below.

The Cayuvava peoples are associated with the landscape west of the Mamoré and north of the Rio Yacuma within west central Mojos. They had many villages along the Iruyañez river and are also associated with the large lakes to the north such as lake Rogoaguado. Padre Augustin Zapata visited the Cayuvava in 1693 and "reported seeing seven villages, averaging 1,800 people each, ruled by one chief" (Denevan 1966:50). He witnessed rituals involving feathered costumes, a large fire burning day and night, and the sacrifice of deer, rabbits, and birds (Denevan 1966:50). Block (1994) notes the lack of corroborating reports of large populations among the Cayuvava in later accounts. He insinuates that early reports of large organized populations may have been exaggerated; however, no consideration is given to the seasonal movement of populations across the larger region such as is suggested by Walker (2018). Archaeological excavations have confirmed the presence of multiple large permanent settlements along the Iruyañez river as well as smaller settlements in the savannas north of the Iruyañez (Walker 2014).

The Movima peoples were reported to concentrate their settlements along the Rio Yacuma as well as the Rio Rapulo and Rio Apere. However, Movima place names have been encountered as far north as lake Rogoaguado near the northern extent of the Cayuvava territories. Descriptions of the Movima people by the Jesuits are of naked barbarians who lived in miserable conditions without any organized political systems. However, their territory intersects with the "greatest concentration of causeways and drained fields in the Beni" (Denevan 1966:52). Some

scholars have had trouble attributing such an extensive agricultural landscape to a group of people lacking a centralized political authority (Denevan 1966:52). This point of view does not credit farmers with the ability to create and sustain their own agricultural infrastructure. However, "centralized political systems do not make agriculture work" (Walker 2018:6). Agricultural systems such as those along the Yacuma river were not necessarily constructed in large centralized planning events. These agricultural systems can be organized at the local level by the farmers who construct and tend the landscape over many generations (Walker 2018:16).

Community Social Organization

Padre Agustin Zapata's account of the Cayuvava described several different villages being organized under a single chief known as Paititi. His description may have been an exaggeration of the Spanish legend of Paititi and a lake in the region filled with pearls (Block 1994). In the Baures region, headmen "did not work, had full command during wars and hunts, could impose the death sentence, could decide when a village should be moved, and were in charge of the cultivation of the plants from which drinks were made" (Denevan 1966:46). These men held hereditary positions, kept slaves, only married the daughters of other headmen, and presided over the construction of earthworks. In the Baures region large earthen causeways were constructed to connect different communities across the landscape (Erickson 2000). This is further evidence of the organization of different communities under a centralized political authority (Denevan 1966:46). Baures communities were also distinct from other groups in Mojos in that they surrounded their villages with wooden palisades and ditches several meters deep (Block 1994; Erickson 2006b).

Padre Orellana in 1687 describes more autonomous villages who elected their own headmen on an annual, or perhaps rather seasonal basis (Denevan 1966:46). These headmen held power through charisma and personality rather than inherited power (Metraux 1943:6,7). They would maintain harmony in the community by acting more as advisors rather than rulers and performed functions such as settling disputes between communities or leading small hunting parties (Denevan 1966; Block 1994:27). Areas like west central Mojos have no clear evidence of a centralized authority, however, they still contain large scale modifications to the landscape and signs of an intensive agricultural system (Walker 2018:158,168).

Mojos Settlement Patterns

Mojos settlements were comprised of 'grandes familias' or dwellings that were occupied by extended family groups who shared in domestic chores (Block 1994:25). Village houses were constructed from wattle and daub. At the center of the house was a wooden center post that supported a roof made from grass or palm fronds (Denevan 1966:58-59). A single village could contain hundreds of houses and kitchen structures. Central to every village was a plaza and communal structure known as a drinking house or *bebedero*.

Settlements are described as being spaced along the rivers at regular intervals as well as strung along seasonal streams in the open savanna. Villages could maintain communication networks between river and savanna settlements through networks of seasonal streams as well as networks of landscape features. There is some evidence that communities would periodically divide and relocate from large river settlements to smaller fragmented savanna settlements, however, Block (1994:26) attributes this to sporadic political events or changes in the size of the population rather than a seasonal subsistence strategy.

Walker (2018:89) also notes that forest islands generally follow one of two patterns in west central Mojos. Forest islands are either located atop river levees adjacent to the permanent rivers or they are placed in close proximity to seasonal creeks further out in the savanna. The distribution of Mojos settlements empowered "communities to enter or exit relations with a larger riverine social world, moving with the seasonal changes brought by flooding" (Walker 2018:174).

Mojos Landscape Features

In Mojos, pre-Columbian communities modified the environment to maintain connections between different parts of the landscape and to maximize their exploitation of natural resources (Block 1994). Visible in the satellite imagery today are a variety of landscape features that include earthen causeways, canals, ring-ditches, fish weirs, and a variety of raised agricultural fields (Denevan 1966; Erickson 2000). Each of these features represent an investment of labor into the landscape and had value to the communities that constructed them given their permanence in the landscape (Walker 2018:112).

Causeways

Causeways were created by piling earth excavated from adjacent canals and functioned as raised roadways which could be used to cross flooded parts of the savanna on foot. Causeways are found throughout Mojos and Denevan (1966) estimated more than 1,600km of Pre-Columbian causeways existed in the region. They generally stand above 1m in height and would have been ideal for keeping settlements connected to different parts of the landscape such as the nearby rivers as well as pampas used for farming (Denevan 1966). Erickson (2001:25)

conducted a thorough study of causeways in the Baures region and dated their construction to a period between 2,000 and 400 years ago. Causeways are still used and constructed by modern inhabitants and while a monumental amount of dirt was moved, a small number of people with wooden tools and basic knowledge of the environment could have constructed the Baures causeways. Causeways provided a means of travel across flooded regions, served hydraulic functions by channeling the drainage of rain water, and served as a form of land tenure by permanently marking the landscape with the investment of labor (Erickson 2001).

Canals

Mojos communities also modified the environment in order to maintain efficient routes of travel across both land and water. Denevan (1966) reported finding more than a dozen canals that are potentially artificial and Pre-Columbian in origin. The canals best associated with Indigenous communities are those that were built along causeways as a source of fill for the construction. Artificial canals could have been constructed quite easily by hand and would have been just deep enough to allow for the passing of a canoe well into the dry season. Jesuit accounts report canals in the Baures region being used by communities to transport crops after the water had begun to recede. One particular type of canal, a 'corte', may have been unique to the Mojos region. Traveling around long meanders in a river adds a great deal of distance to a journey that would be much shorter if the river flowed in a straight line. A corte is a canal that is dug across the narrowest point of the meander allowing for the extra distance to be bypassed (Denevan 1966).

Ring Ditches

Large ditched enclosures have been documented across the southern rim of the Amazon basin. In Mojos these enclosures are known as ‘ring ditches’ and are found within forest islands (De Souza et al. 2018). Ring ditches in northeast Mojos are monumental in size compared to those in west central Mojos (Walker 2018:56). They were dug to depths several meters deep and encircling areas more than 1000m in width (Mann 2008; Erickson 2010). The most thorough investigation of ring ditches in Mojos was conducted by Erickson (2010) who proposed several functions including “defense, settlements, elite residences, land and resource markers, animal traps, cemeteries, water management features, and/or public ceremonial spaces.” Though some ring ditches were accompanied by palisades, not all ditches were deep enough to detour crossing and were not likely to hold water long enough to function as a moat (Erickson 2010).

Documented ring ditches in west central Mojos do not have palisades like those in the northeast and were not large enough to be defensive barriers (Walker 2008:422). In most cases the construction of ditches required the clearing of forests within and alongside the ditch. Within these newly cleared areas, economically useful or aesthetically pleasing tree and plant species could be fostered. The forests growing over ring ditches today may represent a form of secondary forests created by human domestication of the landscape (Erickson 2010). While ring ditch construction has been credited to the movement of Arawak speakers throughout Amazonia, ring ditches in west central Mojos are in areas associated with non-Arawak speakers and are inter-mixed with a larger system of raised field agriculture (Walker 2008:426).

Fish Weirs

A Mojos fish weir is similar to a causeway in that it consists of linear segments of raised earth that stretch across the seasonally inundated savannas. Fish weirs differ in that there is a change in the direction of the line segment every 10 to 30m on average, resulting in a structure with a distinct zigzag shape. When the direction of the weir changes, funnel-like gaps are present in the weir creating a limited space for flood waters and aquatic life to pass from one side of the weir to the other. During the wet season fish may migrate through these openings into the flooded savannas to spawn. Later in the season openings in the weirs can be blocked and migrating fish can be corralled within large areas of the savanna as the flood waters begin to recede (Erickson 2000:191). In some instances, Mojos weirs span great distances between forest islands and indicate a level of cooperation between the different communities they connect. They also represent valuable investments in the landscape given their permanence and ability to produce high quantities of food (Erickson 2000:193). Long zigzag structures that resemble fish weirs are currently being mapped from satellite imagery in west central Mojos. The 2019 Archaeological GIS project of the Beni (Proyecto Arqueologico SIG del Beni/ProSIGAB) field team ground surveyed a zigzag structure near the forest island of Miraflores in the Quinato wetland. This structure is a narrow platform of raised earth that makes its way from the forest island out into the wetlands that separate Miraflores from other nearby forest islands (Walker et al. 2019).

Raised Agricultural Fields

There are several types of Pre-Columbian agricultural earthworks or raised fields that were constructed to drain and farm the savanna. These include mound fields, ditched fields, and

large raised field platforms (Walker 2018:116). These different types of raised fields are morphologically distinct and organized into different regions with very little overlap (Walker 2018:116). Each type of raised field involves the draining of ground for farming through the mounding of earth and digging of adjacent canals or ditches. Raised platforms protect crops from flood waters and the intervening canals or ditches create low spots that retain water longer into the dry season (Denevan 1966). As a result of their construction, raised fields have the effect of ecologically engineering a landscape by transforming a savanna ecosystem into a mosaic of different ecosystems with more complex ecological functions and much higher levels of animal and plant diversity (Renard 2012:33). This project examines the area of west central Mojos which is defined by the distribution of large raised field platforms across the region (Walker 2018).

Large Raised Field Platforms

One of the largest modifications to the Mojos landscape is one of the most difficult features to identify and survey from the ground. Scattered across the landscape of west central Mojos are thousands of large rectangular platforms of mounded earth that are today only several cm tall. They are difficult to see from the ground even for an individual familiar with their location from aerial photographs (Figures 5 & 6). The grass growing atop the plleeatforms is less dense than the surrounding area given the better drained soils of the more elevated surface. From the air, the less dense patches of grass make the vegetation appear lighter in color creating a strong contrast with the grass surrounding the field platform (Denevan 1966). Today with readily available satellite imagery, a clearer picture of the extent of large raised field agriculture

is available and more than 40,000 large raised field platforms have been identified in satellite imagery of west central Mojos.

Raised fields in Mojos today range from 10cm to more than 50cm in height above the surrounding savanna. Excavations of the canals between raised fields indicates as much as 20cm of soil have eroded from the tops of the fields into the canals since their abandonment (Walker 2018:109). Estimating a conservative average height of 20cm in Pre-Columbian times, the 120.2 km^2 (12,020 ha) of raised field platforms mapped in this study represent a total of just over 24 million m^3 of soil that was moved during the construction of raised fields. This is a volume roughly 10 times that of the great pyramid at Giza. The construction of raised agricultural fields is thought to have required high inputs of labor (Renard 2012:33). Erickson (1995:93) estimated that constructing a single hectare of raised field required at least 800 person-days of labor, however, their continued maintenance probably required far less than the initial construction. Based on experiments reconstructing large raised fields in Mojos, it is believed that raised fields were constructed by community work parties (Walker, 2001:14). The GIS analysis of large raised fields has shown that fields are clustered into oriented groups in which the estimated carrying capacity of a single field in a group is comparable to the subsistence requirements of a community work party large enough to build the field. It was estimated that small community work parties with as few as 20 individuals could have been responsible for constructing groups of large raised field platforms (Walker 2004:119).

Lee (2017:66) documents a regional pattern in the orientation of raised field platforms to cardinal direction. Based on this pattern, west central Mojos can be divided into a northern and southern region with a distinct transition from one pattern of orientation to the other. The northern distribution of raised fields demonstrates a pattern of fields being oriented on a roughly

north/south or east/west axis. Groups of raised fields are oriented at right angles to each other with one group having all its field oriented on a north/south access and the adjacent field groups having all its fields oriented on an east/west axis. There is a clear 45-degree shift in this pattern in the southern portion of the region where fields are oriented on southeast/northeast or southwest/northwest axis. This distribution of raised fields is difficult to identify at a small scale but is visible in a regional analysis of raised field platforms (Walker 2018:109).

Agricultural Practices of Raised Field Farmers

This section focuses on the agricultural practices or activities that Mojos farmers would have taken part in while constructing and maintaining raised field platforms. Important to a landscape approach to archaeology, discussed more thoroughly in the next chapter, is an understanding of how people move through and experience a landscape (Walker 2018:74-75,103,130). Landscape features such as raised fields afforded a community a continuing variety of practices to maintain and farm those fields. Farmers would pass through the landscape making decisions about when and where to farm and visit their fields for a variety of tasks such as pulling weeds and harvesting crops. Outlining these practices may give insight into how raised fields were managed as a larger system and more importantly how that system was incorporated into other subsistence practices (Bruno 2014:131).

With the exception of restoration projects, all raised agricultural fields in South America are pre-Columbian in origin and currently abandoned (Denevan 2001:23). There are no ethnographic comparisons for raised fields in the Amazon basin (Walker 2018:132). Some insight can be gained from the study of abandoned South American systems and the ethnographic analysis of other farming groups in the Amazon basin. Today raised field farming

takes place in several parts of the Old World (Denevan 2001:236). Direct analogies cannot be made between raised field farmers in Mojos and those in Africa or Europe, however, they do represent an opportunity to examine how other farmers have gone about managing similar earthworks in similar environments.

Farmers who share a common goal of agricultural intensification have historically solved their problems with a variety of different methods and technologies. Not all farmers choose to adopt the same technology or carry out the same methods, however, they do tend to arrive at a common end. For example, the farming of sloped terrain often results in the creation of terraces (Netting 1993:29). The need to drain ground for farming has resulted in the creation of raised agricultural fields in the Americas as well as Africa, Europe and New Guinea (Denevan 2001:236).

In order to intensify an agricultural systems, farmers must increase the total amount of biotic growth that can be supplied by a set unit of land, maintain that increased supply level through multiple seasons and years, and create a regulated and sustainable system with regularly replenished supplies (Netting 1993:29). Netting (1993:29) provides a list of 5 signs of permanent agriculture that can be detected in a landscape. "They include 1) moving and manipulating soil to feed and foster plant growth and to control erosion, as in deep tilling, ridging, and terracing of permanent fields; 2) regulating water by increasing its supply through irrigation or removing an excess through drainage; 3) restoring or increasing soil fertility by systematic manuring, usually involving the stall-feeding and fencing of livestock, production of crops for fodder and green manure, and the collection and processing of household wastes; 4) diversification of production with a wide variety of cereal, legume, tuber, vegetable, fodder, and tree crops that are interplanted, rotated, and scheduled according to existing microenvironments

and seasonal conditions, and with a range of large and small domestic animals; and 5) protection of plants and animals from growth-inhibiting competition by predation by weeds, diseases, insects, and other pests through guarding, fencing and reducing exposure" (Netting 1993:29). These categories are useful in guiding the discussion of large raised field platforms in Mojos as they illuminate the tasks afforded by an agricultural landscape as well as the ways in which those landscapes can manifest in the material record (Bruno 2014:133). The following review will examine the agricultural practices that Mojos farmers were afforded as part of creating and managing a permanent agricultural system in a seasonally inundated wetland. It is important to remember that while patterns may be visible in the earthworks that farmers create, no single agricultural model or large-scale theory can explain agricultural practices across different contexts (Walker 2018:28). Farmers working in the same environment may ultimately carry out a different set of tasks to meet the same goals.

Moving & Manipulating Soil

One of the signs of permanent agriculture in the landscape is the moving and manipulation of soil (Netting 1993:29). There are few accounts of raised fields being constructed or managed in Mojos, including those of early Jesuits (Denevan 1966:90,95). In the Orinoco, Jesuit missionary Jose Gumilla reported the mounding of earth for cultivation using wooden digging spades (Denevan 2001:217). In some instances, the moving of earth may have first required the clearing of trees (Erickson 2000). Though stone does not naturally occur in Mojos, stone chopping implements have been found at forest islands along the Iruyañez and a broken stone was recovered along the Quinato wetland far from the permanent rivers (Walker 2014; Walker et al. 2019).

This kind of earthwork construction was likely carried out by an organized community work party (Walker 2001:11,12). As part of this process, multiple households would contribute workers to the communal task of traveling out into the savanna, clearing vegetation and then digging and piling earth into raised fields (Walker 2001:11,12). Scatters of painted ceramics have been uncovered near raised field platforms in west central Mojos indicating that community ritual was part of activities surrounding the construction of raised fields (Walker 2018:101-102).

The movement of soil must also be organized over time as raised fields required multiple days or even seasons to construct. It is possible that some work parties traveled to and from new raised field platform on a daily basis for several days or weeks. Others may have camped on the raised field itself or a nearby forest island until the negotiated work was complete (Walker 2018:146-147). If the construction of a field took place in phases over different seasons or years, then this introduces an even more complex set of relationships between communities organizing raised fields and the different work parties that construct them over time.

The task of constructing raised fields also required a large body of indigenous knowledge about farming the local environments (Walker 2014). Modern farmers in the Beni claim that savanna soils are too poor for farming. Soils are regularly leached of their nutrients over time and need to be replenished (Whitney 2014:8). Soils deeper below the surface experience less leaching and may contain higher concentrations of nutrients than surface soils. By removing the appropriate amount of earth, farmers can relocate nutrients from deep within the savanna soils to the top of newly constructed raised field platforms (Denevan 1966:92; Denevan 2001:248). In this context the movement of soil is more of a specialized task than it initially presents.

In the floodplains of the Congo basin, farmers today create raised fields by clearing savanna grass and piling it into large mounds (Comptour et al. 2018). The soil clinging to the

grass roots provides bulk for the field to elevate it above floodwaters and the organic matter of the grass and roots acts as a nitrogen source and compost material. This process can be repeated as the fields grow over with weeds and the soils become depleted of nutrients. In the Congo, raised fields are primarily constructed and managed by women (Comptour et al. 2018:7). It is unknown who took part in community work parties in Mojos, but among other Amazonian farmers, the garden is also primarily the domain of women (Block 1994).

Within the Congo basin raised field construction is strongly related to fishing activities. Field shapes may be altered to act simultaneously as growing surfaces as well as fish corrals and fishing platforms. It is interesting to note that in this region dry season fires are often set to maintain open water routes for boats during the flood season rather than maintain agricultural fields. Raised field farming in this region is not meant to provide all of a farmer’s needs but rather compliment other subsistence systems subject to seasonal fluctuations (Comptour et al. 2018:6,9-10). In this sense a group of farmers may decide to construct new agricultural fields in response to changes in the market for fish or the relocation of fish species on the savanna and the changing needs of the farmers.

Regulating Water

One of the earliest and most obvious functions of raised fields was that of drainage (Denevan 1966:84-85). Elevating fields creates raised areas that are better protected from floodwaters. These platforms are separated by narrow canals from which the raised soil was taken. To protect crops from local rainfall, the raised field famers of the Taraco Peninsula of Lake Titicaca maintained a knowledge of the water retention qualities of their fields and responded with varying measures to further protect crops from water. For example, midway

through the rainy season, previously planted tuber crops were protected from rot by the further mounding of dirt. The addition of new soil allows for more moisture to be absorbed on the surface, protecting the tuber below (Bruno 2014:133). When variability in the Mojos environment threatened a raised field with excessive rainfall, farmers could have traveled to their fields and performed similar practices to protect their own root crops from rot. The mapping of modern flood patterns in Mojos has indicated that raised fields may have been intentionally located in locations that experienced less local rainfall and were less susceptible to seasonal floods (Martin 2018).

The construction of raised fields not only creates elevated surfaces of increased drainage, it also creates negative spaces between the fields were the soils for construction were taken (Erickson 1999). Not all raised fields are constructed in landscapes that require drainage, and there are some instances of raised fields built on slopes that were not capable of retaining water in their canals at all (Lombardo et al. 2011:505,508). In Mojos, it is not currently believed that large raised field platforms altered water drainage at a regional scale, however, future research utilizing more accurate digital elevation models has the potential of identifying watersheds in the landscape created by the regional distribution of raised field platforms. The maintenance of canals between raised fields may have been linked to other resource strategies such as the farming of fish and other aquatic plants. Maintaining the water functions of raised fields would be a reasonable activity to require a farmer to travel across the landscape to visit a field.

Restoring Soil Quality

Phytolith analysis has confirmed that maize was being grown on raised agricultural fields near the forest island of El Cerro along the Iruyañez river (Whitney et al. 2014:236). The

presence of nitrogen-intensive crops like maize indicates that raised fields contained higher concentrations of nutrients in pre-Columbian times than they do today (Whitney et al. 2014:239). There are no early accounts of Mojos farmers applying fertilizer to raised fields (Denevan 1966:97), however, the intervening canals between raised field platforms could have been used to recycle nutrients. Aquatic plants and fish could have been farmed in the canals and used as composting material or a type of 'green manure' on the tops of raised fields (Vidya 2014; Erickson 1988:235; Walker 2011:289; Denevan 2001:72). However, geochemical analysis of some raised fields in Mojos did not produce any evidence of changes that would be expected if the fields had been subjected to regular applications of green manure or other fertilizers (Rodrigues et al. 2015:135). It is important to remember that raised fields in Mojos cover an area of more than 100 thousand km^2 in size and are represented by a variety of types. Not all raised fields were managed in the same way as each was part of its own local context.

Farmers of the Taraco peninsula of Lake Titicaca used dung from grazing animals to fertilize fields and constructed animal enclosures atop fields to concentrate the effects. Farmers also fertilized fields with the ash from burnt kitchen waste and vegetation (Bruno 2014). Mojos inhabitants did not domesticate any animals (Walker 2018: 169). While the farmers in the Taraco peninsula utilized a relationship between pastoral activities and agriculture, Mojos farmers have the strong association between agriculture and aquaculture. Large numbers of fish weirs are currently being identified in the west central Mojos landscape as available satellite imagery continues to improve. Erickson (1988) proposed that large numbers of decomposing fish could be used as a source of fertilization for raised field platforms. On the coast of Peru, farmers utilized an abundance of anchovies to fertilize maize crops. Fish for use as fertilizer was

transferred from the coast to the highlands and there are indications that fish were used to fertilize raised agricultural fields in the Lake Titicaca region (Denevan 2001:35).

Charcoal recovered from lake core sediments in west central Mojos confirm that farmers were manipulating the landscape with the use of fire (Whitney et al. 2014). In an agricultural field fire may be used to clear land as well as manipulate the quality of the soil based on the types of material burned and the types of ash left as a result. Fires not only manipulate soil characteristics with the creation of ash but also warm the fields by charring them black and increasing the amount of sun the field absorbs during the day. For Amazonian farmers the use of fire was a complex undertaking that required an established body of indigenous knowledge (Denevan 2001:39,40).

Another form of replenishing nutrients is through a system of fallowing or placing fields in short periods of disuse so the nutrients in the soil can be replenished. It is important to remember that fallowing does not equate to complete abandonment of a raised field (Posey 1985:144). In contrast, fallow periods may be periods used to promote the growth of trees on raised fields or other plants that could be used for fiber resources, medicines, or construction materials such as palm fronds for the building of roofs.

Farmers can locate fields in separate zones spread across a larger region allowing each zone to go in and out of fallow in response to local weather patterns. Spreading crops out spatially can create a type of flexibility, giving farmers more choices in regulating fallow patterns based on local conditions (Denevan 2001:43,44,46). The Kayapó of the Xingu region of the Brazilian Amazon, though not constructing raised field platforms, practice a form of nomadic agriculture in which they walk exceptional distances to tend forest gardens far from their villages (Posey 1985:148-149). Treks into the forests could last for a month at a time and would cross

areas several hundred kilometers wide between the Tocantis, Araguaya and Amazon rivers. The Kayapó would trek through the forests gathering economically useful plants and transplanting them to concentrated garden plots spread throughout the region (Posey 1985: 149). These garden patches do not receive the same labor inputs as a swidden fields but are still visited enough for minor management efforts like weeding and relocating newly gathered plants (Denevan 2001:41,42).

Ultimately a variety of activities for replenishing field nutrients were available to Mojos farmers. Archaeological evidence confirms that nutrient-intensive crops like maize were being grown on raised fields in west central Mojos (Whitney et al. 2014). By tapping into a body of indigenous knowledge, Mojos farmers took part in a variety of tasks that improved the conditions of local soils.

Crop Diversification

Unlike industrial forms of intensive agriculture that emphasize monocropping, traditional kin-based agricultural systems controlled by a household usually intercrop a variety of different wild and domesticated plants in their fields (Netting 1993:29). Jesuit Padre Castillo provided a list of plants cultivated by Mojos communities: maize, beans, squash, sweet potato, peanut, papaya, red pepper, cotton, a variety of edible tubers, tobacco, and plantains (Denevan 1966:99). Paleobotanical evidence such as starch grain and phytolith analysis has confirmed that maize, squash, peanuts, cotton, and palm fruits were all cultivated near settlements in eastern Mojos. Whitney et al. (2014) provides evidence of maize and sweet potato cultivation on large raised field platforms near El Cerro forest island in west central Mojos. Paleobotanical evidence also

indicates that Mojos farmers were domesticating several species of plants and trees including yuca, peach palm, pepper, peanut, urucu, and cocoyam (Walker 2018:44).

Indigenous forms of agriculture outside Mojos organize a variety of crops spatially and sequentially to raise overall productivity. For example, bean stocks are often planted with maize crops to aid in the fixing of nitrogen into the soil. The stalks of the maize plants become support structures for the bean vines to grow upon. Peanuts are another nitrogen fixing plant that may be intercropped with maize to replenish soils between harvests (Denevan 2001:40,41).   The use of intercropping techniques is another example of pre-Columbian farmers tapping into a body of indigenous knowledge about the different tasks that would aid in intensifying an agricultural system.

The process of intercropping a raised field would have required the collection and transportation of a variety of different plants to the field being planted. The Achuar of western Amazonia intercrop their forest gardens as a type of pleasurable pursuit rather than for the function of increasing productivity (Descola 2016). These activities of caring for and enjoying interactions with different plants give humans an opportunity to develop and maintain more complex relationships with the non-human things with which they care for. Diversifying a raised agricultural field in west central Mojos could have required a farmer to travel great distances across the region in order to collect and transplant different species of plants to their fields.

Crop Protection

Weeding fields is one of the most basic methods of protecting and managing crops. When removing weeds, the farmer may select which plant species to protect and which to remove. Weeds can also be controlled by “burning, by mulching, by shading via multiple

canopies, and by companion cropping of allelopathic species (Denevan 2001:47-48)." The longer that an agricultural field is continuously cropped, the greater its susceptibility to pests and weeds. Ultimately weed control may be a greater factor in fallowing cycles than crop fertility (Denevan 1966:94; Denevan 2001:45). By spreading out their fields spatially, farmers may shift their cultivation from one area to another transitioning their fields into fallow as pests and weeds become abundant in the current area being cultivated. Spreading fields out spatially also allows for farmers to protect their crops from flocks of birds or natural disasters that affect a single part of the region.

Insects are one of the primary problems related to agriculture. Flooded forests and permanent wetlands provide excellent breeding grounds for aquatic insects which have higher levels of diversity than plants and animals that are better studied (Goulding et al. 1996:71-72). Planting a diverse group of crops aids in protecting harvests from insects. Certain species of plants may repel insects chemically while others may provide habitats for predators that feed on insects and reduce their numbers. When planting a variety of crops together, one group of plants may pass through stages of reproduction and growth at different periods than other groups, creating a constantly changing environment for pests. The density of any single species in a field is reduced with more diverse crop choices. This results in harvests being less susceptible to a single predator (Denevan 2001:40,41).

Outside of Mojos, several methods have developed to protect crops from ant predation in Amazonia. The Bora people of northwestern Amazonia use crushed basil leaves to make solutions of ant repellent for peanut plants. The Kayapó of the Xingu region of Amazonia transplant a species of Azteca ant to their agricultural fields and forested areas to compete with and repel colonies of leaf cutter ants that are highly destructive to crops and useful species of

trees (Posey 1985:144; Denevan 2001:47). One of the most effective means of protecting crops from predators such as birds and small animals is the constant presence of humans. A large range of activities are also possible when considering the ritual activities that may have been involved in protecting crops from pests (Denevan 2001:47).

All of the agricultural activities that revolve around maintaining a landscape of raised fields incorporate a variety of different tasks that require a farmer to move between forest island and field and back again several times throughout a season. A large portion of the landscape can be experienced in the process of canoeing up a seasonal stream or trekking across the savanna to tend raised fields. Raised fields can be interacted with for a variety of reasons while a farmer passes through the landscape for other activities such as fishing or foraging. All of these practices tapped into a body of indigenous knowledge that was developed over several generations (Erickson & Walker 2009:250). The creation of raised agricultural fields invested in the landscape a lasting form of capital that could be accessed by this knowledge.

CHAPTER 3: LANDSCAPE APPROACH

Within South America, archaeologists have a long history of attempting to associate environmental change with cultural change (Walker 2012:310). Early efforts to characterize tropical rainforest cultures in Amazonia emphasize the high regional variation and linguistic diversity of a people who shared many common traits despite being dispersed across such a vast geographic area. Relating so much cultural variation to environmental variation has long been problematic (Steward 1946:1-3). Areas described simply as 'tropical forest' are actually a more complex mosaic of savanna and forest ecosystem that do not coincide with such sharp changes in cultural variation (Steward 1946:1-3). Steward applied biological evolution to culture, making sweeping generalizations about how cultures could adapt to various environments leading to a linear form of cultural evolution (Grinker 2008:263). Meggers (1971) made similar connections between different traits of tropical rainforest cultures and their ecological settings. Characteristics of societies that inherently reduce population size, such as increased tribal warfare or infanticide, were thought to be the result of the environments limited ability to maintain large populations. Human societies had to develop their own mechanisms for reducing population size to prevent resource networks from collapsing. Ultimately, populations were thought to be restricted in size and complexity by the dispersed and unreliable resources of a tropical rainforest ecosystem (Meggers 1971).

Today a landscape approach attempts to place culture and nature in an interdependent relationship rather than one affecting or limiting the other (Walker 2012:310; Anschuetz et al.2001). With strong influences from human geographers such as Carl Sauer, a landscape approach begins with a recognition that human societies have a spatial dimension and that

through the process of adapting (or dwelling) in their environment they produce a landscape that is a kind of repository of cultural activity (Sauer 1925; Darvill 2008:61). This repository gives the landscape a time-depth component like a form of horizontal stratigraphy that can be read like a text (Johnson 2008). Agricultural landscapes like those in Mojos are the result of multiple generations of farmers working and modifying the land creating a palimpsest of accumulated activities (Denevan 2001; Erickson & Walker 2009:233; Erickson 2006:350). However, the landscape does not only receive modifications from the farmers. Cultural landscape features like raised fields also shape the actions of future farmers due to their lasting effect on the landscape. Accumulated landscape features can be valuable assets to populations that inherit the landscape, like a form of capital invested in the land that remains after a crop is harvested (Erickson & Walker 2009; Brookfield 2001:55). In Mojos, raised agricultural fields could act as a form of land tenure, marking the labor of past farmers on the landscape (Erickson & Walker 2009:234).

A Siteless approach

A landscape approach also aids the archaeologist in shifting the scale and focus of the investigation out towards the larger landscape rather than the individual site. The discussion of the material record expands from a concentration of sherds to include the larger landscape features that were also part of past people's daily lives. Archaeology as a discipline has been criticized for the creation of the fundamental archaeological unit of a 'site' (Dunnell 1992). Mainstream spatial analysis on 'settlement patterns' revolve around the distribution of 'sites' representing important places of extended habitation (Kowalewski 2008:227). These important places are identified by an increase in the accessibility of material remains, often found through survey (Kowalewski 2008:227). Ultimately, sites are defined and represented by relatively high

and continuous densities of artifacts mapped on a grid network. These artifacts are associated by proximity alone and do not necessarily have the same depositional history. Concentrations of artifacts must be related through events of deposition to be used as analytical units for archaeological interpretation (Dunnell 1992:26,33,36). As a result, sites should not be thought of as fundamental units that are observable or discoverable within the material record and should not be the primary unit of analysis for archaeologists.

Dunnell (1992) proposes a siteless approach to archaeology in which the artifact rather than the site acts as the empirical unit of observation. The archaeological record is not a collection of site and non-site locations but rather a "continuous distribution of artifacts" that can be aggregated together in interpretively meaningful ways (Dunnell 1992:34). The most basic unit is the individual artifact rather than the bounded site; this unit can be built up with other artifacts of related deposition into larger interpretive units (Dunnell 1992:34). The area of study becomes the chosen focal point at which the archaeologist can make reasonable interpretations of the material record and the past historical processes that took part in its creation. This ability to shift scales provides a view of Amazonia that looks beyond a cluster of trees or a single forest island to a larger landscape that is representative of a more complex and interdependent relationship that humans have had with their environment. Interpreting Mojos settlement patterns within the landscape will require moving beyond the analysis of forest islands and raised fields as discreet sites but rather emphasizing how people experienced the larger landscape while incorporating these landscape features into their daily lives.

Society & Nature

A landscape approach to interpreting the past also takes into consideration that pre-Columbian South Americans formed complex social relationships with non-human living things (Walker 2012). Western society operates with an ontology that makes a clear distinction between culture and nature. The earliest city-states with large walled cities solidified a division between culture and nature that did not exist previously. The walls of a city separated members of society from a chaotic or wild world on the outside and created a tame and ordered lifestyle within. Inherent in this division is an ongoing struggle between society and a nature that is considered hostile and chaotic (Hughes 2001:34-35).

Pre-Columbian communities of the Bolivian lowlands did not make the same distinction between their own communities and the natural ecosystems from which they subsided. In Amazonian communities, people form social relations with plants and animals that westerners do not (Descola 2013; Walker 2018:32). When the Achuar of western Amazonia clear a patch of forest to create a garden, they do not make any distinctions between a place that is wild and a place that is tame and ordered. Forests are not wild places that are separate from human gardens but are larger gardens that are tended by a forest spirit in the same way a human garden is tended to by the Achuar farmers (Descola 2013). In their gardens the Achuar mix a variety of domesticated as well as wild species of plants though they make no distinction between the two types.

The gardens created by the Achuar are an iconic representation of the surrounding forest that is tended by the spirit gardener. The Achuar organize their garden plants in a way that mimics the same ecological processes that are visible in the surrounding forest. To the Achuar the garden becomes a representation of a miniature forest which they must care for as the spirits

care for their own garden forests. Achuar gardens are not functional but rather a pleasurable pursuit as ‘gardeners’ take pleasure in the collection of widely distributed forest species into their gardens in an attempt to mimic the high diversity found in the surrounding forest (Descola 2016:7-8). Of note here is the cross-over between the use of the terms farming and gardening. In western society today the term farmer implies growing crops for profit or surplus. The term gardener on the other hand emphasizes a more household-based subsistence system as well as a pleasurable past-time. Perhaps for the Amazonian farmer the distinction is less important. Large raised fields in the savannas have the same potential as social actors as the smaller garden plots planted adjacent to settlements. An abandoned agricultural field in the Mojos savannas can become a community of plants and animals that replaces the communities of crops tended by human farmers (Walker 2018).

Taskscapes

Moving further from an initial emphasis on the physical environment, Ingold (1993) defines a landscape as the actual experience of dwelling in an environment. The environment is not something ‘natural’ that surrounds humans but rather becomes part of them. Any part of the landscape is viewed as unique but also embodying some part of the whole. A place is then characterized by the experience it affords and the types of activities that inhabitants choose to engage in. By dwelling in a place, individuals carry out particular tasks that are related to that landscape. Tasks may be individually listed but are intrinsically linked to larger groups of tasks related to the landscape and to the encompassing social networks that surround daily life. Ingold (1993:158) proposes the use of a ‘taskscape’ to represent the interlocking nature of different tasks linked to the creation and maintenance of a landscape. When viewed as events in a

sequence, the tasks of a taskscape have a social temporality to them that links each task to the previous task and the next task never isolating tasks from the landscape that is carried along with the community that dwells there. A feature like an agricultural field could have an array of tasks such as the organization of a work party at a community festival to the pulling of weeds.

Anthropogenic Landscapes in Mojos

Walker (2014) and Walker (2018) utilize the taskscape approach developed by Ingold (1993) to compare different agricultural landscapes in Mojos based on the tasks required to create and maintain the landscape itself. Different landscapes require and afford a different overlap of tasks making some landscapes more complex than others. If the construction of a raised causeway interferes with the function of a nearby agricultural field, then cooperation will be required between the farmers with interests in the conflicting tasks. When comparing different agricultural landscapes in Mojos, some taskscapes are more complex than others (Walker 2014).

Walker (2018:115-116) identified seven anthropogenic landscapes within Mojos based on the close association of landscape features including raised agricultural fields, causeways, fish weirs, habitation mounds and ring ditches. Within each landscape the close association of landscape features afforded a different set of tasks that were available to pre-Columbian communities as they negotiated the landscape. Ultimately these features and their associated tasks were part of the identity of the people who continued to invest labor in the landscape. Each of the seven landscapes are distinctive but not isolated from one another (Walker 2018:112-13). The focus of this project is West Central Mojos (WCM) which is at the center of these seven

landscapes and is defined as any area within 10km of a large raised field platform as will be discussed in the next chapter (Walker 2018).

West Central Mojos Landscape Units

Walker (2018) utilizes six categories of landscape tasks ("farming, construction, hunting, water control, fire control, and transportation") to analyze different clusters or 'constellations' of landscape features representing community level taskscapes acting on the landscape. These constellations and the immediate area of the landscape that surrounds them are referred to here as Landscape Units.

Landscape Units

As part of a landscape approach, areas of the landscape are analyzed based on the variety of tasks that members of a community carry out to construct and maintain patterned groups of landscape features (Walker 2018). For example, areas with numerous raised fields as well as permanent rivers afford inhabitants a wide range of tasks relating to farming on raised fields as well as trade and transportation along permanent rivers. While carrying out these tasks members of a community moved between forest island and raised field and river experiencing larger portions of the landscape than just the platforms of raised fields or the interior of a forest island. Areas of the landscape with fewer or no agricultural fields and no permanent rivers may be associated with other tasks such as setting fires on the savanna, hunting game or visiting a seasonal fishing hole. Landscape Units represent ways in which the permanent modifications to the landscape had the potential to pattern the daily activities of the communities who dwelled there.

There is no ethnographic comparison to indicate at what distances a set of landscape features become more or less associated with one another. For this project, a series of suitability maps are created for each of the four Landscape Units described below. These suitability maps represent the proximity of each portion of the landscape to a given landscape feature. Suitability maps are created by buffering each of the vector-based datasets and assigning a ranking value to each of the buffered regions identified. All vector-based maps were converted to 500m x 500m rasters for combination into Landscape Suitability Maps. By combining multiple suitability maps into a single map, an interpretation can be made as to the distribution of any given Landscape Unit across the entire landscape. All Landscape Unit maps are created and analyzed as 500m x 500m rasters so they may be combined together to analyze their distribution and overlap with one another across the landscape. These 500m cells are by no means meant to represent the mobility limits of pre-Columbian peoples. Movement is not restricted within cells but rather each cell is meant to represent a patterned set of activities available to inhabitants passing through that part of the landscape. In this sense the landscape can be experienced even through a raster map of the landscape by allowing the viewer to understand and imagine the different activities that potentially exist within each cell and how those activities are distributed across the region.

Neighborhood Landscape Units

These Landscape Units are defined as any area of the landscape within close proximity of a raised field Neighborhood. They are constructed from a vector-based map of all raised field Neighborhoods in Mojos. Raised field Neighborhoods are represented by groups of raised field platforms close enough in proximity to prevent new fields being built between existing fields

(Walker 2018: 100). Isolated fields more than 40m from the nearest raised field are uncommon and most raised fields are found in Neighborhoods as well as oriented groups (Lee 2017). Individual raised field platforms could have been constructed by community work parties (Walker 2001) and the size of an oriented group is comparable to the carrying requirements of the work party needed to construct the field (Walker 2008). A Neighborhood in this sense represents a level of organization one step above that of the oriented groups and raised field platforms. A Neighborhood's fields were not all constructed in one event or planned sequence of events but share some level of cooperation among the same community of individuals investing in the landscape.

"Communities that built and maintained Neighborhoods were obviously concerned with the construction, maintenance, and farming tasks associated with the field platforms, but also with fire management… Community ritual on and near Neighborhoods of raised fields must be considered in light of the dense scatters of painted ceramics found near the field Neighborhoods in the San Juan Landscape" of west central Mojos (Walker 2018:101-102).

Buffer Landscape Units

Buffer Landscape Units are defined as any area of the landscape that lacks a strong association with either raised field Neighborhoods or forest island landscape features. These Landscape Units are interpreted from a combined landscape suitability map representing each portion of the landscape rated on its combined distance to the nearest forest island as well as raised field Neighborhoods. "The buffer landscapes… are the places where the fewest community tasks are evidenced. Although hunting could still be important, and fishing is possible, the remoteness of these places makes it most likely that they are used as places to

escape from unwanted interaction or to reduce conflict between communities" (Walker 2018:102).

Archipelago Landscape Units

In west central Mojos, seasonal streams run from the permanent flowing rivers out into the more remote areas of the savanna. Walker (2018) reports groups of small forest islands with associated raised field Neighborhoods strung along these streams both close to the permanent rivers as well as further out in the savanna. Archipelago Landscape Units are defined here as any area of the landscape with strong associations to seasonal streams, small raised field Neighborhoods and small forest islands (<=0.8ha). These Landscape Units are interpreted from a combined landscape suitability map representing each portion of the landscape rated on its combined distance to the nearest seasonal stream, small forest island, and small raised field Neighborhood combined.

"Archipelago communities were less concerned with the farming and construction of raised fields and perhaps more with transportation either in a positive sense (connecting to a larger riverine transportation system) or in a negative sense (avoiding contact with people along the navigable rivers). Fishing could be seasonally important, as some populations of fish head out into the savanna during the wet season, to return in the fall" (Walker 2018:102).

Agropolis Landscape Units

In west central Mojos strong associations have been noted between large forest islands and large concentrations of raised field Neighborhoods (Walker 2018). Agropolis Landscape Units are defined as any area of the landscape with strong associations to large forest islands,

large concentrations of field Neighborhoods and one of the permanent flowing rivers or major wetland systems. These Landscape Units are interpreted from a combined landscape suitability map representing each portion of the landscape rated on its combined distance to the nearest large forest island, large raised field Neighborhood, and permanent river or major wetland.

"Agropolis communities utilize the broadest spectrum of potential tasks, including all the tasks associated with field Neighborhoods and adding the tasks associated with large occupations, including transportation through the large, navigable rivers. If community history and ritual are important, ring ditches are larger, denser populations suggest that Agropolis landscapes might be where these tasks took place. And many fishing tasks are associated with oxbow lakes along the rivers" (Walker 2018:102). Agropolis Landscape Units represent areas of the landscape where the greatest variety tasks intersect together in one location on the landscape.

Regional settlement pattern analysis

Mojos presents an excellent case study for a landscape approach to analyzing regional settlement patterns based on the distribution of Landscape Units across the landscape. Kowalewski (2008) provides a list of properties to help guide settlement pattern research questions. Each of these ten properties is applicable to the settlement patterns of raised field farmers in west central Mojos. Collectively they demonstrate how west central Mojos can benefit from a regional approach to settlement pattern analysis.

Place & Scale

West central Mojos is definable by the near continuous distribution of raised field platforms. A buffer of 2,000 m around all raised field platforms nearly combines the entire

population of raised fields into a single unit (Table 1). This means that a farmer could theoretically walk from field to field, moving between more than 40,000 fields across the landscape and rarely walk more than 2,000m between fields. A buffer of 4,151m is required to collapse the entire population into a single region with no separate parts. The discrete border for west central Mojos outlined by Walker 2018 and utilized in this project is any area within 10km of a raised field platform. The resulting study area or spatial territory is 10,281 km^2 in size. Population estimates may also be derived from the distribution of discrete forest islands within this region as forest islands may be used as proxies for permanent settlements.

Complexity

West central Mojos can be differentiated into different parts based on the distribution and arrangement of cultural features on the landscape. Lee (2017) divides west central Mojos into two distinct regions based on the occurrence of raised agricultural fields of specific orientations. This project further divided west central Mojos into different landscape units based on the tasks the landscape afforded as outlined by Walker (2018). These Landscape Units connect across the landscape representing more complex interactions across the region.

Integration

The movement of rivers across the landscape provides a type of integration that connects the landscape as rivers integrate to the east. The permanent rivers act like highways or avenues integrating a city, giving commuters access to the central parts of the region. Networks of seasonal streams link the permanent rivers up to more remote areas of the savanna. Areas like the Quinato wetlands and Miraflores forest island are remote areas far from the permanent rivers.

Seasonality allows these remote areas to flow in and out of connection with the permanent rivers. Examining the integration of different landscape units and their connections between river and savanna locations is a primary goal of this project.

Boundedness

This study demonstrates that west central Mojos has a clearly defined internal and exterior portion. As previously discussed, a buffer of only 4,151m around raised field Neighborhoods creates a single polygon within ArcMap. This polygon has no internal parts that are not within 4,151m of a raised field Neighborhood. Increasing this buffer to 10,000m as suggested by Walker (2018) provides a clearly bounded study area. Large raised fields platforms are not found outside this region and there is very little overlap between raised field platforms and other types of raised fields such as mound or ditched fields.

While raised field platforms are the defining feature of west central Mojos, preliminary analysis indicates that there are small portions of the landscape that are less populated with raised fields and forest islands than other areas. The mapping of Landscape Units further demonstrates how large concentrations of raised fields mark a clear outside area of west central Mojos from an internal area that is surrounded by raised field Neighborhoods.

Forest islands also provide a clearly bounded proxy for permanent settlements given the clear distinction between forest and surrounding savanna. A majority of surveyed forest islands in west Central Mojos contained pre-Columbian ceramics on their surfaces with no continuous collections of finds extending into the savannas (Walker 2004; Walker 2018:71). This makes the distribution of forest islands in west central Mojos an excellent proxy for the distribution of pre-

Columbian settlements within the landscape. However, forest islands extend beyond the boundary of west central Mojos as a region and are not bounded within it.

Efficiency

A region suitable for settlement pattern analysis should have an established economy based on finite resources (Kowalewski 2008:254). Raised agricultural fields represent a form of intensive agriculture that would be a part of the local economy. The incorporation of other subsistence practices such as hunting and fishing are indicated in the ethnographic record as well as in the presence of permanent fish weirs that are continuing to be discovered in west central Mojos. The discovery of stone implements in west central Mojos also confirms that these communities were taking part in trade with outside regions (Walker 2014; Walker et al. 2019).

In order to meet subsistence needs in a seasonal environment, communities in Mojos incorporated a large range of activities that stretched from river to remote savanna regions at different times of the year (Block 1994). The distribution of raised field platforms across such a broad geographic area may have also provided flexibility in periods of exceptional flooding and increased loss of crops due to floods.

Variation

West central Mojos is different from the other raised field landscapes in Mojos given the presence of large raised field platforms. These platforms are not found outside of west central Mojos; however, other types of raised fields are. It is not yet clear why large raised field platforms were the raised field of choice in this region compared to others.

The identification of Agropolis and Archipelago Landscape Units is intended to identify variation within the regional settlement patterns. Once identified, landscape units may be compared with each other to identify differences and similarities between them. For instance, raised agricultural fields near the forest islands of Cerro have been noted as being smaller on average than the larger population of raised fields (Walker 2014; Lee 2017). If Cerro and its surrounding fields correlate to an Agropolis landscape unit, then its landscape afforded a slightly different kind of field than other Agropolis regions identified. Associating an agricultural field to any forest island or settlement pattern is problematic without exact dates for each field.

Embedding

To be considered embedded, regional settlements should have definable neighboring settlements as well as being a component that is nested within a larger system (Kowalewski 2008:254). The seven anthropogenic landscapes described by Walker (2018) appear to be nested together in a larger system of permanent agriculture. West of the Mamore river the landscapes overlap with each other with distinct zones being dedicated to particular types of raised field construction. West central Mojos is embedded between a group of ditched fields that neighbor it to the northwest and a group of mound fields that neighbor it to the southwest. The bulk of field types are clearly independent of each other, but they do blend together at their borders with some overlap between field types and with permanent rivers and wetlands flowing between them.

Duration

Early radiocarbon dates for occupation in west central Mojos go back to the early first millennium CE (San Juan forest island). Forest islands are thought to be occupied continuously

with dates extending into post contact periods (Cerro forest island) (Walker 2018:21,45,47). Farmers were manipulating the west central Mojos landscape "for at least 2,500 years, and probably for at least 7,000 years (Walker 2018:107)." Analysis of charcoal and pollen in lake core sediments near the El Cerro forest island demonstrate an agricultural history going back at least as far as AD 310 (Whitney et al. 2014:236,240).

Descent

Identifying areas of descent with modification is problematic given the difficulty of directly dating an agricultural field. Potential patterns exist in the morphology of raised fields as well as their general size. For example, mound fields are found in a region distinctly separate from raised fields with very little overlap and a chronology between these two field types is not yet established. Areas of increased and decreased field size have been identified within the distribution of large raised field platforms, such as the concentration of consistently smaller agricultural fields in the northern portion of the region (Lee 2017). To what extent these regions are related to each other chronologically is not yet clear.

Based on these observations, west central Mojos is an excellent case study for a regional settlement analysis with several clear avenues for possible research questions. In Mojos, large raised agricultural fields are easily identifiable and mappable in aerial survey. This project identifies an area of more than 100,000 km^2 definable by the presence of raised field platforms alone. Mojos satellite imagery provides a sharp contrast between forest and savanna ecosystems. Mapping Mojos forest islands represents a variable of permanent settlements distributed across the entire region. Spatial analysis of this regional data has the potential of finding patterns in the distribution of the communities represented in the organization of the landscape.

Objectives & Hypothesis

This project uses a landscape approach to interpret the regional settlement patterns of pre-Columbian raised field farmers. A landscape approach to west central Mojos has the potential of clarifying how different parts of the landscape were incorporated together into a more complex seasonal subsistence system. The pre-Columbian landscape was reconstructed with an emphasis on the tasks that Mojos farmers were afforded by different combinations of landscape features in any given area. The analysis examined the relationships between three primary sets of spatial data: forest islands, raised agricultural fields and water networks. The primary objective was the creation of four maps representing the distribution of Agropolis, Archipelago, Neighborhood, and Buffer Landscape Units as identified by Walker (2018:100-101). A combined map of the four different Landscape Units allows for interpretations as to the movement and interactions of different agricultural communities across the landscape.

It was hypothesized that mapping Landscape Units in west central Mojos would demonstrate how large permanent settlements were part of a complex seasonal subsistence pattern that alternated between river front areas and remote savanna locations. Seasonal networks of streams can temporarily link isolated chains of forest islands up to the larger river networks. As the dry season sets in these locations become isolated from the main river and must be traveled to by foot. Pre-Columbian communities were able to exploit a wider range of natural resources and utilize the constantly changing environment to remove themselves from river front activities and interactions during some parts of the year and return again at others (Walker 2018). This research demonstrates the integration of river and remote savanna locations by the linking and overlap of different types of Landscape Units across the landscape and the patterned ways in which they are organized in relation to one another. Landscape Units with less

integration would present as dispersed Units that do not connect or overlap in patterned ways but instead exist in separate isolated regions.

CHAPTER 4: METHODS

The methodology for this study is broken down into four sections. The first is the collection and organization of three independent data sets. The data for this project includes digitized maps of raised field Neighborhoods, forest islands, and water networks. The second section is the use of the 3 data sets to create 9 suitability maps which rate the landscape based on proximity to the landscape features represented in the three data sets. Maps of large raised field Neighborhoods were used to create 4 different suitability maps based on the proximity of different portions of the landscape to raised field Neighborhoods of different sizes. Maps of forest islands were used to create 3 different suitability maps based on the proximity of different portions of the landscape to forest islands of different sizes. Maps of water networks were used to create 2 different suitability maps which rate the landscape based on proximity to permanent as well as seasonal water networks.

The third section combines and interprets the suitability maps in order to create 4 separate maps, one for each of the 4 types of Landscape Units identified by Walker (2018:100-101). The Landscape Units include: Neighborhood Landscape Units, Buffer Landscape Units, Archipelago Landscape Units and Agropolis Landscape Units. The fourth section measures a variety of characteristics of each individual Landscape Unit that is identified so that comparisons can be made between Landscape Units of the same type. The fifth and final section analyzes how the different types of Landscape Units are organized in relation to one another across the landscape and to what extent they overlap.

Data

At the University of Central Florida, student volunteers for the Archaeological GIS project of the Beni (Proyecto Arqueologico SIG del Beni/ProSIGAB) have been using software such as Google Earth and ArcMap to digitize archaeological features from open source satellite imagery. To date this group has mapped more than 60,000 pre-Columbian raised agricultural fields, 4,000 forest islands, several hundred kilometers of river and water network, and hundreds of other features such as contemporary farms, visible ring ditches, earthen causeways, and fish weirs. Figures 7 & 8 show how a landscape feature such as a raised field platform is first identified in satellite imagery, then mapped/digitized with georeferenced polygons. This digitized spatial data is then uploaded to GIS software such as ArcMap for further spatial analysis. The first stage of this project was to utilize ArcMap to sort through spatial data in the ProSIGAB database and select from it a layer of data in which each individual archaeological feature of interest (raised agricultural field, forest island, and water network) was represented by a single polygon.

Raised Field Data

Working with a body of data created by crowdsourcing has advantages and disadvantages. This project analyzed ProSIGAB spatial data going back as far as Boothby (2010) and included the work of more than a dozen different digitizers working at different periods of time on satellite imagery from a variety of platforms and time periods. The quality of available imagery is constantly improving (Figure 9) and issues such as cloud cover in one year may be improved in another year. Even when features can be readily identified in satellite imagery, their exact shape and outlines are not always so easy to distinguish and mark on a map.

For instance, when cattle move from one raised field to another, they trample down the ends of the agricultural fields making them appear to blend together into one single field. Other fields have well preserved ends that can be drawn out neatly with little question. To further complicate the problem students often overlap their work adding new fields to the database while re-mapping fields that were previously identified.

Utilizing methods from Lee (2017), the project database was analyzed to create a data layer representing all raised field platforms in which each field was represented by a single non-overlapping polygon. Figure 10 demonstrates how a single polygon was selected from a larger overlapping group created by multiple users. The area of intersect between the polygons was measured and any polygon with more than 25% of its total area overlapping with other polygons was removed until one polygon per agricultural field remained. This methodology favors larger agricultural fields and assumes that overlaps below 25% generally represent two different field platforms with overlapping digitizing work. Small intersects below 25% were examined individually to ensure two separate fields were present. Ultimately if two fields were present then the overlapping region was merged back into the polygon with the longest shared border.

In aerial photographs as well as satellite imagery, raised field platforms are generally rectangular in shape even if they appear to be eroded in sections. To conform to this observation and check the quality of the data, the perimeter to area ratio of each polygon was calculated to identify non-rectangular polygons. Non-rectangular polygons were singled out and examined individually in satellite imagery before being removed from the dataset. Non-rectangular polygons in the dataset are often the result of two different agricultural fields being digitized as a single field or a circular feature like a forest island being digitized as a raised field platform.

There are non-rectangular raised agricultural fields in west central Mojos, however, there are few areas where these field types overlap with rectangular field platforms (Walker 2018).

With updated imagery also comes the discovery of new raised field platforms. Lee (2017) using similar methods created a layer of 40,472 polygons. This project ultimately utilized a GIS layer of 44,224 polygons. This increase in fields though relatively low compared to the entire layer is localized in areas with updated imagery that were searched for fields and updated as part of this project. A significant number of field platforms were discovered in the Quinato area where only 2,640 fields were identified by Lee (2017). There are sections of the landscape that appear to contain raised fields in the satellite imagery. Unfortunately, the fields in these areas are not preserved well enough in the imagery to mark their full borders with confidence. For the purpose of this analysis this dataset is believed to be a near complete representation of raised field platform distribution within west central Mojos. However, more fields are still being identified in satellite imagery and maps are continuing to be refined by the work of researchers and students. This dataset does not include a variety of other raised field types that are present in Mojos but are only encountered on the edges of west central Mojos such as an expanse of mound fields to the southwest. It should also be noted that some raised field platforms are difficult to distinguish from ponds towards the northwest portion of the region and several large groups of fields were omitted from the project for this reason. However, their numbers are not significant compared to the other fields in the northern portion of the study area.

Raised Field Neighborhoods

When trying to sort fields into organized groups one of the simplest relationships that can be inferred is between two fields that are immediately adjacent to one another. When one field is

built next to another field it takes up limited space available for a group of farmers to expand and build more fields next to ones currently in use. The assumption here is that building one field adjacent to another required some form of cooperation between those who had rights to access the fields. The next step in the study was assigning each field into a local Neighborhood grouping based on proximity to nearby fields. Each Neighborhood is given a custom identification number in the GIS and was analyzed for attributes such as overall size and field count.

Preliminary analysis of the data revealed an average distance of less than 10m between any platform and the nearest neighboring platform. The average width of a platform was estimated to be approximately 20m. Platform width measurements were taken with the Minimum Bounding Geometry tool but since no field is perfectly rectangular this measurement was slightly skewed towards a higher value and 20 was selected as a more accurate estimate based on manual measuring of sampled polygons. Based on these figures it was determined that 40m was the minimum width of an area needed to construct a raised field platform. This includes 20m for the platform itself and another 20m for the two canals (10m wide each) on either side of the platform. A 40m estimate is consistent with methods used by Walker (2004) in creating raised field Neighborhoods based on proximity. Raised fields with less than 40m separating them are more closely associated with one another because there is not enough room between the fields to build another field. The construction of one field has impacted the adjacent field by taking up a limited amount of space allowing fields to be constructed side by side. Platforms with more than 40m separating them from adjacent platforms are less associated as there was enough available space for more fields to have been constructed between them. Intentionally spacing fields apart from one another may have been a basic unit of organization and is the basis for the raised field

Neighborhood designation. Figure 11 shows how in ArcMap polygons representing raised field platforms were first united with the spatial join tool and then assigned a Neighborhood ID based on shared spatial joins no greater than 40m. Figure 12 shows a larger selection of field platforms symbolized by their Neighborhood ID.

In this study no field platform could be assigned more than one Neighborhood identification. Individual fields isolated from all other fields by more than 40m were still assigned Neighborhood identifications, though their Neighborhood count was only 1 platform. Lee (2017) demonstrates that individual field platforms are relatively rare compared to the larger population of raised field platforms. Their distribution still represents a set of tasks available to farmers experiencing the landscape afforded by these platforms. The Neighborhood identification will be used later in the project to create maps of the distribution of raised field Neighborhoods based on the number (count) of individual platforms that make up the individual Neighborhood. Archipelago and Agropolis landscape units to be created as part of this project will require maps of both large and small Neighborhood groups as per their definition by Walker (2018:100-101).

Neighborhood-based Study Area

Walker (2018) defines west central Mojos as any area within 10km of a raised field platform. Raised field Neighborhoods are the only landscape feature mapped in this project that are completely restricted to west central Mojos by definition. Forest islands and water networks exist in and around west central Mojos. The forest island and water network data sets discussed below were selected based on their intersection with a study area polygon representing the

borders of west central Mojos. A study area was created based on the known location of raised field platforms and a 10-km proximity rule described by Walker (2018).

First, all 4,444 raised field Neighborhoods previously identified with the 40m proximity rule were selected and individually buffered 40m to demonstrate their distribution on the landscape. These Neighborhood buffers were then buffered again in increasing increments to measure the distribution of Neighborhood groups across the study area and to determine at what distance of buffer would all raised field platforms be collapsed into a single neighborhood (Figures 13 & 14; Table 1). This single Neighborhood was then buffered the remaining distance required to reach a 10km study area. This study area represents an outer border for west central Mojos that is consistently 10km from the edge of the nearest raised field platform (Figure 15).

The Neighborhood-based study area is a polygon used to mark the borders of west central Mojos as well as select out forest island and water network polygons for use in the analysis. By definition, all raised field platforms are within the study area polygon; however, forest islands and water networks extend beyond the study area in every direction (Figure 16).

Forest Island Data

Boothby (2010) provided the first and to date still the most extensive digitized map of forest islands across west central Mojos. This map was expanded upon in 2016 by ProSIGAB member Paula Grisales who spot-checked much of the data for accuracy against newer imagery and pioneered an effort to georeference all the archived data going back to 2010. In 2019 as part of this project, all available forest islands from the project database that fell within the study area were selected and compared to the most recently available satellite imagery in ArcMap. An

extensive forest island by forest island check was made to ensure properly georeferenced polygons and to evaluate whether forest islands were being accurately represented.

Like the digitizing of agricultural fields, identifying and mapping forest islands also has problems that must be overcome. While some forest islands have very sharp margins that can be seen on an image, many do not. Forest islands can have gradients of forests along their borders. If the forest island itself is the mounded high ground, any slope away from the mound may provide a gradual decrease in forest cover and a transition to scrubland that blurs the distinction between forest island and the surrounding area. Some forest islands are tucked in amidst the gallery forests of rivers and may be more difficult to distinguish from the surrounding canopy. This problem can be overcome first by the careful checking of polygons against the imagery. Subtle differences in canopy cover or distinctly rounded forest edges can help identify forest islands or the mounds beneath their canopy. More recently a world terrain model has been made available in ArcMap which makes it possible to compare maps of forest islands to their corresponding elevation data (Figure 17). This process makes the borders of some forest islands easier to map when their margins are covered with gradients of different forest types.

Another distinction that must be made is between forest islands and patches of forests growing atop raised agricultural fields. In the northwest region of the study area large sections of forest were removed from the project dataset of forest island polygons because the forest margins are restricted to the surface of the rectangular field platforms with no trees growing in the intervening ditches (Figure 18). It is difficult to determine whether these areas represent permanent settlements since they are both non-circular and lack strong association with ceramic finds. It is also unclear what role the fields play in the origins of the forest given the lack of growth in the surrounding canals. Many of these forests are scattered across what appear to be

meandering river levees from an abandoned paleo-river channel. Like the river levees along the rivers further south, there are still patches of high ground and solid forest areas that can be selected out as forest islands from the larger levee areas. The total amount of forest island surface area analyzed in any west central Mojos project will vary depending on how this type of forest cover is treated. This project included a layer of 1,940 polygons representing 8,786.4ha of forest island that intersected with the project study area (Figure 19). These figures do not include gallery forests or scrubland and only include circular to irregular forest islands with clear boundaries.

Permanent & Seasonal Water Networks: Rivers, Streams & Wetlands

There are four permanent rivers that cross the west central Mojos landscape: the Iruyañez, Omi, Yacuma and Rapulo. Though they vary from one another in size and sediment load, each meander across the region from southwest to northeast following larger channels left by abandoned paleo-rivers (Figure 20). These permanent rivers are the easiest water networks to identify due to their correlation with surrounding gallery forests. For this project, each of the four rivers were mapped by tracing their banks along both sides following the areas where the water meets the forest canopy. This methodology produced a polygon representing the location of the rivers surface outside the forest. Gallery forests were also mapped as separate polygons and it is important to remember that the river does expand and flood these areas also. River polygons were converted to center lines in order to measure the lengths of the rivers and their meanders.

Though technically not a flowing river, the Quinato wetland was also digitized as a permanent water network for the purpose of this project. The transition from savanna grasses to reeds and other aquatic plants is very clear in satellite imagery of the Quinato and the entire

wetland was digitized as a single polygon. The wetland is surrounded in all directions by savanna as well as seasonal streams.

Each of the permanent rivers contain arroyos and stream networks that branch off into the surrounding savanna, however, many of these secondary water sources are seasonal rather than permanent. As the stream networks move further into the savanna the reduction of the gallery forests is notable in the satellite imagery. In the savanna, unforested stream networks are difficult to distinguish from cattle trails and modern roads and canals. Due to this observation, only the most visible savanna stream networks were mapped with the criteria that their paths be traceable back to some part of the permanent and forested sections of the river system. Savanna stream networks often move in and out of a mosaic of marshes and swamps. In areas where permanent wetlands were most identifiable, they were digitized as polygons to capture their more distinguishable margins. Most stream networks, however, were digitized as polylines marking the center of the stream network. The stream polylines were buffered into 5m wide polygons to represent the stream networks. Only the four permanent rivers with permanent forests along their banks had both banks mapped individually (Figure 21).

Landscape Suitability Maps

There is no ethnographic analogy to define how far a raised field farmer travels to carry out any particular activity. The suitability maps allow for the landscape to be rated based on the availability of the landscape features affording the tasks in question. A ranking system of 1,2,10 is used for this project. A ranking of 1 represents an area of the landscape that is highly suitable for association with the landscape feature being analyzed. A ranking of 2 represents an area of the landscape that is further in distance from a landscape feature than an area with a ranking of 1

but is still close enough to be associated with the feature. A ranking of 10 represents an area of the landscape that is least associated with the landscape feature being analyzed. This methodology allows the entire study area to rated based on suitability for consideration as part of different Landscape Units.

The purpose of the ranking system is so that suitability maps associated with the landscape features that make up Landscape Units may be combined together to demonstrate the different ways Landscape Units may be represented. Moving away from one feature on the landscape may result in simultaneously moving towards one or two other feature types. There are no set criteria for determining at which distances landscape features become more or less associated with one another. The creation of a Landscape Unit map is an interpretation of the different ways that a portion of the landscape may be associated to one or more landscape features. All suitability maps were created by the buffering of vector-based data and then converted to 500m x 500m rasters with Ranking values assigned to each cell.

Neighborhood Suitability Map 1: Neighborhoods of Any Size.

Neighborhood Suitability Map 1 is a map of west central Mojos in which all areas of the landscape have been rated based on their proximity to raised field Neighborhoods. The purpose of Neighborhood Suitability Map 1 is to provide an interpretable map from which the areas determined most suitable for the Neighborhood Landscape Unit Map are selected for analysis in section 3 of this chapter. To create the suitability map, all the polygons representing raised field Neighborhoods were buffered in 1km increments for 2km total (Figures 22 & 23). This divides the landscape up into three zones of suitability. The portions of the landscape within 1 km of a raised field Neighborhood are assigned a Ranking value of 1, indicating that they are highly

suitable for consideration as part of the Neighborhood Landscape Units. Portions of the landscape within 1 to 2km of a raised field Neighborhood are assigned a Ranking value of 2, indicating that they are of intermediate suitability for consideration as part of the Neighborhood Landscape Unit. Portions of the landscape further than 2km from a raised field Neighborhood are not considered suitable for consideration as part of the Neighborhood Landscape Unit and were assigned a Ranking value of 10 (Figure 24).

The decision to rate the first 2km of the landscape is based on several initial observations. First, a buffer of 2,000m around each Neighborhood created 7 individual polygons spread across the entire study area (Table 1). Increasing the total area considered beyond 3,000m nearly collapses the entire population of raised fields into a single region. It is desirable for comparison with other Landscape Units that the map of Neighborhood Landscape Units contain more than a single Unit.

Second, the average distance between a raised field Neighborhood and the nearest raised field Neighborhood is only 136m (s = 214m) for the entire distribution of raised field Neighborhoods. When examining only those raised field Neighborhoods with a field count between 27 and 97 fields, the average distance increased to just over 1km and continues to increase as the size of the Neighborhoods increases (Table 5). Examining raised field Neighborhoods with more than 97 fields results in an average distance of more than 3km between Neighborhoods. Buffering the landscape in 1km increments for 2km allows for a great deal of variation in Neighborhood distribution to be captured in each 1km increment while stopping short of a buffer large enough (3km) to rate the entire landscape as being associated with raised field Neighborhoods. The mobility of a raised field farmer is not believed to be

restricted to small 1km zones of activity. The model created here only serves to rate the landscape based on locations where certain activities are most likely to be taking place.

Neighborhood Suitability Map 2: Neighborhoods of Any Size With Reversed Order.

Neighborhood Suitability Map 2 rates the entire landscape based on proximity to raised field Neighborhoods. This is similar to Neighborhood Suitability Map 1 except that preference is given to areas at increased distances from raised field Neighborhoods rather than in close proximity. The purpose of Neighborhood Suitability Map 2 was to be combined with Forest Island Suitability Map 1 to create a single Buffer Suitability Map that outlines all regions of the landscape that are the least suitable for farming activities and could be interpreted as part of the Buffer Landscape Unit Map.

Neighborhood Suitability Map 2 was created by reclassifying Neighborhood Suitability Map 1 to reverse the Ranking order (Figures 25 & 26). Areas of the landscape with strong associations to raised field Neighborhoods are not suitable for consideration as part of a Buffer Landscape Unit. In Neighborhood Suitability Map 2, preference was given to areas at greater distances from raised field Neighborhoods. Areas falling within 1 km of a raised field Neighborhood were reclassified as a value of 10 identifying them as unsuitable for consideration as part of the Buffer Landscape Units. Areas falling between 1 and 2km from a raised field neighborhood were reclassified as a value of 2, identifying them as intermediate suitability for a buffer region. Areas that are more than 2km from a Neighborhood were reclassified as a 1 identifying them as highly suitable locations for buffer regions when considering raised field Neighborhoods alone.

Neighborhood Suitability Map 3: Large Neighborhoods

This first two Neighborhood Suitability maps treat all raised field Neighborhoods as equal. Neither Neighborhood Landscape Units nor Buffer Landscape Units require a suitability rating that differentiates between Neighborhoods of different sizes. Archipelago and Agropolis Landscape Units, however, require that portions of the landscape be rated based on the size of a nearby raised field Neighborhood as well as the size of the nearby forest island.

Identifying large and small raised field Neighborhoods first required selecting the criteria for large and small. The two obvious options for quantifying Neighborhood size are area and platform count. Figure 27 demonstrates how large Neighborhoods could be selected either by the total area comprising the Neighborhood, the average size of an individual field within the Neighborhood, or a count of all individual field platforms comprising the Neighborhood. To determine a cutoff point between large and small, the list of all Neighborhood sum areas, and sum platform counts were set in individual lists and grouped into the five natural breaks in the dataset (Table 2). Figure 21 demonstrates a comparison of the different cutoff values when the top three natural breaks are selected to represent large raised field Neighborhoods. Raised field Neighborhoods with a sum platform area of more than 40ha fall into the top three natural breaks. When measuring the size of a raised field Neighborhood by the number of platforms in a neighborhood, the top three breaks are represented by Neighborhoods with a platform count of 98 or more.

Looking at Figure 27, the selection of large Neighborhoods by average platform size seems to exaggerate the presence of large Neighborhoods by identifying a vast majority of Neighborhoods as large. Identifying Large Neighborhoods by sum platform slightly underrepresents the presence of Large Neighborhoods. This underrepresentation is clearest north

of the Iruyañez where raised field Neighborhood have smaller platform sizes on average than other areas in west central Mojos (Lee 2017, Walker 2014). However, these maps indicate that those small fields still comprise large Neighborhoods when measured by their platform count rather than sum surface area. Ultimately large and small Neighborhoods were represented by platform count for this project.

When the number of platforms in each Neighborhood was examined, 98 was identified as the third break and selected as the cut off point for a Neighborhood to be considered 'small' or 'large' (Figure 28). Including smaller field Neighborhoods from the second break included almost every region where Neighborhoods are located and did not assist in identifying Neighborhoods from which interpretations could be made. The fourth break was determined to be too restrictive and did not identify large Neighborhoods south of the areas surrounding the confluence of the Iruyañez and Omi rivers. The fourth break also identifies only six Neighborhoods out of 4,444 (Table 3). Regional patterns in the organization raised fields have been reported (Lee 2017) and identifying large Neighborhoods throughout these larger regions is necessary. Platforms are relatively consistent in size across each of the breaks (Table 4). At the third break in the data, the average distance between two Neighborhoods of the same break ranking triples (Table 5). Larger Neighborhoods ranked within the third break or higher are distributed further apart from each other than the smaller Neighborhoods scattered all about.

Ultimately the third break in the data (>=98 platform count) was chosen as the clearest division between classifying field Neighborhoods as either small (<98) or large (>=98). A value of 98 is also nearly 10 times the average size (10 platforms per Neighborhood) of all Neighborhoods in the dataset. Raised field Neighborhoods with a count of 98 fields or higher have

a significant distribution across the entire study area but are still big enough to distinguish from a Neighborhood of average size.

Having determined a cutoff value for large field Neighborhoods, Neighborhood Suitability Map 3 was created. Neighborhood Suitability Map 3 is a basic representation of all areas on the landscape that may be considered within proximity of large raised field Neighborhoods. The purpose of Neighborhood Suitability Map 3 was to provide an interpretable map from which the areas determined most suitable for the Agropolis Landscape unit map were selected for analysis in section 3 below.

To create Neighborhood Suitability Map 3, all the polygons representing large raised field Neighborhoods were buffered in 1km increments for 2km total (Figures 29). This divides the landscape up into three zones of suitability. The portion of the landscape within 1km of a large raised field Neighborhood were assigned a Ranking value of 1, indicating that they are highly suitable for consideration as part of the Agropolis Landscape Units. Portions of the landscape within 1 to 2km of a large raised field Neighborhood were assigned a Ranking value of 2, indicating that they are of intermediate suitability for consideration as part of the Agropolis Landscape Unit. Portions of the landscape further than 2km from a large raised field platform were not considered suitable for consideration as part of the Agropolis Landscape Unit and were assigned a Ranking value of 10 (Figure 30).

Neighborhood Suitability Map 4: Small Neighborhoods

Neighborhood Suitability Map 4 was created using a platform count of 97 as a cutoff value for small raised field Neighborhoods. Neighborhood Suitability Map 4 rates the entire landscape based on proximity to small raised field Neighborhoods. Areas closer to small raised field

Neighborhoods are considered more suitable than areas further away. The purpose of Neighborhood Suitability Map 4 is to provide an interpretable map from which the areas determined most suitable for the Archipelago Landscape unit map are selected for analysis in section 3 below. Neighborhood Suitability Map 4 will be combined with forest island Suitability Map 3 and the Seasonal Water Network Suitability Map in order to create a Combined Archipelago Suitability Map.

To create Neighborhood Suitability Map 4, all the polygons representing small raised field Neighborhoods were buffered in 1km increments for 2km total (Figures 31). This divided the landscape up into three zones of suitability. The portion of the landscape within 1 km of a small raised field Neighborhood was assigned a Ranking value of 1, indicating that they are highly suitable for consideration as part of the Archipelago Landscape Units. Portions of the landscape within 1 to 2km of a small raised field Neighborhood were assigned a Ranking value of 2, indicating that they are of intermediate suitability for consideration as part of the Archipelago Landscape Unit. Portions of the landscape further than 2km from a small raised field platform are not considered suitable for consideration as part of the Archipelago Landscape Unit and were assigned a Ranking value of 10 (Figure 32).

Forest Island Suitability Map 1: Forest Islands of Any Size

Forest Island Suitability Map 1 is a basic representation of all areas on the landscape that may be considered within proximity of a forest island of any size. The purpose of Forest Island Suitability Map 1 was to provide an interpretable map from which the areas determined most suitable for the Buffer Landscape Unit map were selected for analysis in section 3 below. To create Forest Island Suitability Map 1, all the polygons representing forest islands were buffered

in 1km increments for 2km total (Figures 33 & 34). This divides the landscape up into three zones of suitability. The portions of the landscape within 1km of a small raised field Neighborhood were assigned a Ranking value of 1, indicating that they are highly suitable for consideration as part of the Archipelago Landscape Units. Portions of the landscape within 1 to 2km of a small raised field Neighborhood were assigned a Ranking value of 2, indicating that they are of intermediate suitability for consideration as part of the Archipelago Landscape Unit. Portions of the landscape further than 2km from a small raised field platform are not considered suitable for consideration as part of the Archipelago Landscape Unit and were assigned a Ranking value of 10.

Forest Island Suitability Map 2: Large Forest Islands

Large forest islands were first identified with the same methods as the large Neighborhoods. The surface area of each forest island was placed in a list and divided into groups based on the five natural breaks (Table 6). Figure 35 demonstrates how the selection of forest islands changes between the second third and fourth breaks. Selecting all forest islands above the second break significantly decreases the number of polygons in the dataset, however, it still includes a majority of the forest islands located adjacent to the permanent water networks (Figure 35; Table 7). The fourth break and above reduced the selection to exclude documented Agropolis landscapes such as San Juan which is less than 30ha in size. A selection above the third break (26.3ha) included all previously documented large forest islands associated with Agropolis Landscapes.

The average distance between forest islands of the same rank triples at the third break (Table 8). Forest islands of this size are becoming more dispersed though still in close proximity

of other small islands. This is a much broader distribution than is found when comparing forest islands of smaller sizes. If this limit is reduced below the third break in small increments, an increasing number of forest islands are selected along the permanent rivers and along the Quinato wetland. However, it is interesting to note that no large forest islands above the third break in the data are found along the Omi. Based on these observations, the third break (26.3 ha) was selected as the cut off for large forest islands.

It is also observed that large forest islands are found adjacent to strips of gallery forests that can be more than a kilometer in width. Due to these observations the scale of buffering for large forest islands was doubled from 1 to 2km and multi-ring buffers were created to a maximum of 4km. This larger buffer will also be discussed when examining permanent water networks in the next section.

Forest Island Suitability Map 2 is a basic representation of all areas on the landscape that may be considered within proximity of a large forest island. The purpose of Forest Island Suitability Map 2 is to provide an interpretable map from which the areas determined most suitable for the Agropolis Landscape Unit map are selected for analysis in section 3 below. To create Forest Island Suitability Map 2, all the polygons representing large forest islands were buffered in 2km increments for 4km total (Figures 36 & 37). This divided the landscape up into three zones of suitability. The portions of the landscape within 2km of a large forest island were assigned a Ranking value of 1, indicating that they are highly suitable for consideration as part of the Agropolis Landscape Units. Portions of the landscape within 2 to 4km of a large forest island were assigned a Ranking value of 2, indicating that they are of intermediate suitability for consideration as part of the Agropolis Landscape Unit. Portions of the landscape further than

4km from a large forest island are not considered suitable for consideration as part of the Agropolis Landscape Unit and were assigned a Ranking value of 10.

Forest Island Suitability Map 3: Small Forest Islands

Walker (2018) identifies small circular forest islands of less than 0.8ha in size as a characteristic of the Archipelago landscape unit. Forest Island Suitability Map 3 is a basic representation of all areas on the landscape that may be considered within proximity of small forest island less than 0.8ha in size. The purpose of Forest Island Suitability Map 3 was to provide an interpretable map from which the areas determined most suitable for the Archipelago Landscape unit map were selected for analysis in the next section. To create Forest Island Suitability Map 3, all the polygons representing small forest islands were buffered in 1km increments for 2km total (Figures 38). This divided the landscape up into three zones of suitability. The portions of the landscape within 1km of a small forest island were assigned a Ranking value of 1, indicating that they are highly suitable for consideration as part of the Archipelago Landscape Units. Portions of the landscape within 1 to 2km of a small forest islands were assigned a Ranking value of 2, indicating that they are of intermediate suitability for consideration as part of the Archipelago Landscape Unit. Portions of the landscape further than 2km from a small raised field platform are not considered suitable for consideration as part of the Archipelago Landscape Unit and were assigned a Ranking value of 10 (Figure 39).

Seasonal Water Network Suitability Map

The Seasonal Water Network Suitability Map is a basic representation of all areas on the landscape that are considered to be within close proximity of a seasonal stream. The purpose of

the Seasonal Water Network Suitability Map is to provide an interpretable map from which the areas determined most suitable for the Archipelago Landscape unit map are selected for analysis in section 3 below. To create the Seasonal Network Suitability Map, all the polygons representing seasonal streams were buffered in 1km increments for 2km total (Figures 40). This divided the landscape up into three zones of suitability. The portions of the landscape within 1km of a seasonal stream were assigned a Ranking value of 1, indicating that they are highly suitable for consideration as part of the Archipelago Landscape Units. Portions of the landscape within 1 to 2km of a seasonal stream were assigned a Ranking value of 2, indicating that they were of intermediate suitability for consideration as part of the Archipelago Landscape Unit. Portions of the landscape further than 2km from a small raised field platform were not considered suitable for consideration as part of the Archipelago Landscape Unit and were assigned a Ranking value of 10 (Figure 41).

Permanent Water Network Suitability Map

The Permanent Water Network Suitability Map is a basic representation of all areas on the landscape that may be considered to be within close proximity of one of the four permanent water networks identified by Walker (2018). The purpose of the Permanent Water Network Suitability Map is to provide an interpretable map from which the areas determined most suitable for the Agropolis Landscape unit map are selected for analysis in section 3 below. To create the Permanent Water Network Suitability Map, all the polygons representing the 4 permanent water networks were buffered in 2km increments for 4 km total (Figures 42). This divided the landscape up into three zones of suitability. The portion of the landscape within 2 km of a seasonal stream were assigned a Ranking value of 1, indicating that they are highly suitable for consideration as

part of the Agropolis Landscape Units. Portions of the landscape within 2 to 4 km of a seasonal stream were assigned a Ranking value of 2, indicating that they were of intermediate suitability for consideration as part of the Agropolis Landscape Unit. Portions of the landscape further than 4 km from a small raised field platform were not considered suitable for consideration as part of the Agropolis Landscape Unit and were assigned a Ranking value of 10 (Figure 43).

The 2km buffer zones are larger than those used in previous suitability maps. The amount of landscape taken into consideration for these maps was increased for several reasons. First, rivers are digitized by following their borders where the visible channel of water meets the surrounding gallery forests. However, the gallery forests flood and also represent a portion of the river at different times in the season. A 1km buffer like those used in other suitability maps is not large enough to account for this changing width in the river and still make meaningful interpretations of the data regarding what is near and far from the river.

Second, previous spatial analysis by Garcia-Cosme (2016) examined a sample of landscape features within 700 and 1000m distances from the permanent river networks in portions of west central Mojos. Increasing increments from 700 to 1000m produced significant differences in the number of landscape features selected (Garcia-Cosme 2016:49) indicating that greater buffer distances are required to capture patterns in the distribution of landscape features along the permanent rivers. For this reason, 2km increments were chosen to represent areas of significance along permanent rivers.

Lastly, increasing the total amount of suitable landscape being considered to 4km is more appropriate for comparing riverfront areas to savanna areas given the great distance between rivers. The average distance between the Iruyañez and Omi rivers is 12,159m (s = 5,923m). This is calculated by plotting points every 500m along each river then measuring the distance from every

point on one river to its closest point on the other river. With more than 18km of savanna separating the rivers in some locations, an area of 4km along the riverbanks is more appropriate for dividing the region up into meaningful sections that measure the distribution of objects in relations to the rivers. Where a 4km buffer around Neighborhoods would not allow for meaningful interpretations to be made, it is appropriate for landscape features that are measured in relation to the permanent rivers.

Landscape Units

As part of a landscape approach, areas of the landscape are analyzed based on the classes of communal tasks that were carried out to construct and maintain that portion of the landscape (Walker 2018:101). For example, areas with numerous raised fields as well as permanent rivers have strong associations with tasks relating to farming as well as trade and transportation along the river. Areas of the landscape with fewer or no agricultural fields and no permanent rivers may be associated with other tasks such as hunting. Walker (2018) identified four groupings or 'constellations' of landscape features that represent classes of communal tasks afforded by those patterned combinations of features. These constellations of landscape features and the immediate area of the landscape that surrounds them are referred to here as Landscape Units. These Landscape Units represent ways in which the permanent modifications to the landscape had the potential to pattern the daily activities of the communities living there. Landscape units are selected from Suitability Maps that represent the proximity of any portion of the landscape to a combination of landscape features.

The purpose of this section is to outline how the different suitability maps are combined and interpreted in order to create Landscape Unit Suitability Maps and finally Landscape Unit

Maps. Each of the four Landscape Units is individually defined below and the required Suitability Maps are analyzed to determine the portions of the landscape to be identified as a Landscape Unit. Walker (2018:100-101) has provided a basic definition outlining the groups of landscape features that can be associated with the different Landscape Units. However, there is no guide to explaining at what proximity these features are more or less related to one another. An interpretable set of suitability maps allows for a range of Landscape Unit distributions to be considered.

Neighborhood Landscape Units

The Neighborhood Landscape Units are a representation of the portions of the landscape with the strongest association to raised field Neighborhoods. Raised field Neighborhoods are groups of raised field platforms organized such that each platform is no more than 40m from at least one other platform in the Neighborhood. A raised field Neighborhood can be associated with a variety of tasks like pulling weeding, planting clippings, cleaning canals, or harvesting crops. All these activities require moving back and forth between forest island, Neighborhood and water network. This can mean traveling several kilometers across the landscape, influencing where and when people visit different areas. A map of Neighborhood Landscape Units allowed for an analysis of the ways in which agricultural tasks were distributed across the region. It also allowed for an analysis as to how those agricultural activities overlap or interact with other sets of landscape features and the activities those features afforded inhabitants.

The Neighborhood Landscape Unit Map had only 1 factor to consider for suitability: proximity to raised field Neighborhoods. Neighborhood Suitability Map 1 (Figure 24) was interpreted to determine which zones of suitability would be included in the map of

Neighborhood Landscape Units. With a buffer of 1km around all raised field Neighborhoods, a total of 56 individual regions are created across west central Mojos (Table 1). When the buffer is increased to 2km, the number of regions created drops to only seven. A purpose for mapping Landscape Units across west central Mojos is to compare the characteristics of different units and how they are organized across the landscape. A 1km buffer allows for an area immediately adjacent to raised fields to be identified without completely blurring the boundaries between different Neighborhood Landscape Units across the larger region.

Another purpose of the Neighborhood Landscape Unit Map is to be compared and combined with the other Landscape Units (Buffer, Archipelago, Agropolis) created in the study. All portions of the landscape identified as Neighborhood Landscape Units were assigned a value of 1 in a raster map of the landscape (Figure 44). Buffer Landscape Units will be identified in the next step and assigned a value of 2. Archipelago Landscape Units will be assigned a value of 3 and Agropolis Landscape Units will be assigned a value of 4. These values will help demonstrate the different ways that the Landscape Units combine and overlap together across the landscape.

Buffer Landscape Units

The Buffer Landscape Units are a representation of the portions of the landscape that lack a strong association with either raised field Neighborhoods or forest island landscape features. A lack of forest islands and raised field Neighborhoods has been recognized along a short leg of the Omi river and there are several areas in the mid pampas where these landscape features are absent (Walker 2018:101). Walker associated these locations with a reduction in community

activities taking place such would be found in buffer regions that prevent conflict between different communities.

The Buffer Landscape Unit Map had 2 factors to consider for suitability: The first was proximity to raised field Neighborhoods which was measured in Neighborhood Suitability Map 1 (Figure 18). The second factor was proximity to forest islands which was measured in Forest Island Suitability Map 1 (Figure 34). These two suitability maps were combined using a raster calculator in ArcMap to sum the values from both rasters into a single value (Figure 45). Landscape regions identified with a Ranking of 1 for both Suitability Maps resulted in a value of 2 for the Combined Suitability Map. Regions that were ranked unsuitable (10) for one layer and were ranked highly suitable (1) for another layer would result in an 11 in the Combine Suitability Map. These combined maps make up the Buffer Combined Suitability Map (Figure 46). Using a value of 10 for unsuitable zones makes those zones easier to single out when combined with ratings based on other features. A portion of the landscape that does not contain an unsuitable rating for all of its associated features will never have a combined value greater than 6. Finding a value of 10, 20, or 30 indicates how many times a particular area was rates as unsuitable for a particular set of activities.

The purpose of the Buffer Combined Suitability Map is to provide a range of possibilities for the selection of Buffer Landscape Units across the region. The first value to consider in the combined suitability map is any rating below a value of 10. These ratings include all areas of the landscape considered to be suitable without any unsuitable (10) values being included. If the minimum suitability value for a Buffer Landscape Unit is reduced from below 10 to below 4, the identifiable Buffer Landscape Units are reduced in size across the region but not significantly reduced in number. What this means is that there are several distinct Buffer zones identified

near the center of the study area that are not removed from consideration by reducing the suitability value required to create Buffer Landscape Units. Figure 47 shows how all optimal codes that did not contain a value of 10 were selected as Buffer Landscape Units and reclassified as a value of 2. All other areas of the landscape were reclassified as a value of 0. This map will combined with the Neighborhood Landscape Unit Map (Value 1), the Archipelago Landscape Unit Map (Value 3) & the Agropolis Landscape Unit Map (Value 4) later in this chapter.

Archipelago Landscape Units

Archipelago Landscape Units represent any area of the landscape with strong associations to seasonal streams, small raised field Neighborhoods, and small forest islands. The communities utilizing these combination of landscape features "were less concerned with the farming and construction of raised fields" than Agropolis communities given the lack of large raised field Neighborhoods (Walker 2018:102). These Landscape Units were interpreted from a Combined Suitability Map representing each portion of the landscape rated on its combined distance to the nearest seasonal stream, small forest island, and small raised field Neighborhood combined.

The Archipelago Combined Suitability Map had 3 factors taken into consideration as part of its creation: The first is proximity to small raised field Neighborhoods, measured in Neighborhood Suitability Map 2 (Figure 26). The second is proximity to small forest islands, measured in Forest Island Suitability Map 3 (Figure 39). The third factor is proximity to seasonal water networks (Figure 41). These three suitability maps were combined using a raster calculator to sum the values from both rasters into a single value (Figure 48). Landscape regions identified with a 1 for all three suitability maps sum to a value of 3 in the combined suitability

map. Regions that were unsuitable (10) in one suitability map highly suitable (1) for the other two Suitability Maps, sum to a value of 12 for the Combined Suitability Map. If all three Suitability Maps rate the same area as unsuitable (10) then the Combined Suitability Map would identify that area with a sum value of 30. These combined maps make up the Archipelago Combined Suitability Map (Figure 49).

Figure 50 demonstrates the different possible cut off values for the Archipelago Landscape Units based on the Archipelago Combined Suitability Map.   The difference between a suitability Ranking of 6 and of 12 is whether or not a single unsuitable (10) Ranking value is taken into consideration along with two highly suitable values. Allowing a value of 10 to be considered when two other highly suitable values are assigned gives the Archipelago definition a bit of flexibility allowing two highly suitable factors to make an exception for a third unsuitable factor.   Increasing the Ranking consideration above a value of 12 blurs the boundaries between Archipelagos of different regions into one large indistinguishable Unit that was not useful for interpreting regional patterns within the distribution.

Based on these figures, all summed values of 12 or less in the Archipelago Combined Suitability Map were reclassified as a value of 3 which is the unique code for Archipelago Landscape Units assigned in this project (Figure 51). Neighborhoods Landscape Units were previously assigned a code value of 1, Buffer Landscape Units a code value of 2, and now Archipelagos Landscape Units are assigned a code value of 3. In the next section Agropolis areas are identified and coded with a value of 4 so that the intersection of Landscape Units with one another can be analyzed.

Agropolis Landscape Units

The Agropolis Landscape Units represent any area of the landscape with strong associations to the four permanent water networks, large raised field Neighborhoods, and large forest islands. This constellation of landscape features afforded inhabitants the greatest variety of tasks associated with farming as well as large permanent occupations, long-distance travel through navigable rivers, and fishing in oxbow lakes (Walker 2018:102). These Landscape Units were interpreted from a Combined Landscape Suitability map representing each portion of the landscape rated on its combined distance to the nearest permanent water network, large raised field Neighborhood, and large forest island.

The Agropolis Combined Suitability Map had 3 factors taken into consideration for rating the landscape. The first was proximity to small raised field Neighborhoods, measured in Neighborhood Suitability Map 4 (Figure 32). The second factor was proximity to large forest islands, measured in Forest Island Suitability Map 2 (Figure 37). The third factor was proximity to permanent water networks (Figure 43). These three suitability maps were combined using a raster calculator in ArcMap to sum the values from each raster into a single value (Figure 52). Landscape regions identified with a 1 for all three suitability maps summed to a value of 3 in the Combined Suitability Map. Unsuitable regions (10) in one suitability map but highly suitable (1) for the other two suitability maps, summed to a value of 12 for the Combined Suitability Map. If all three Suitability Maps rate the same area as unsuitable (10) then the Combined Suitability Map will identify that area with a sum value of 30. The result of this combination is the Agropolis Combined Suitability Map (Figure 53).

Next, the Agropolis Combined Suitability Map was interpreted to select out those zones most suited to represent the Agropolis Landscape Units. Figure 54 provides an example of two

of the cut off values that could have been chosen for the Agropolis Landscape Units based on the Agropolis Combined Suitability Map. The main decision was whether or not to include any suitability rankings above the value of 10. Many more areas of the Landscape are selected if one of the required landscape features is not in close proximity. The selected areas also become larger in size when less suitable areas of the landscape are considered. To produce a Landscape Unit Map with a definition closest to that provided by Walker (2018) no unsuitable regions (Ranking 10) were included in the study. All values less than a 6 in the Agropolis Combined Suitability Map were reclassified as a value of 4 which is the unique code for the Agropolis Landscape Units assigned in this project (Figure 55). Neighborhood Landscape Units were previously assigned a code value of 1, Buffer Landscape Units a code value of 2, and Archipelago Landscape Units a code value of 3. Later in this chapter these code values will be used to combine the four Landscape Unit Maps (Figure 56) into a Combined Landscape Unit Map (Figure 57). The purpose of the Combined Landscape Unit Map is to demonstrate how the four different Landscape Units are organized in relation to one another on the Landscape and how they overlap and intersect.

Landscape Unit Analysis

Having created maps of the four types of Landscape Units, it becomes possible to count and measure each isolated unit. The total area covered by each unit was compared to the area of the whole study area to determine what percentage of the landscape was affected by that type of task group and what percentage of the study area is left undefined after all four types of Landscape Units are combined.

In order to make comparisons between Landscape Units, the characteristics of each Archipelago & Agropolis Landscape Unit were measured in ArcMap. For example, each polygon representing an Agropolis Landscape Unit (Figure 55) was intersected with the layer of polygons representing raised field Neighborhoods as well as forest islands. The characteristics of each Neighborhood and forest island falling within the boundaries of the Landscape Unit were measured and averaged together to describe that particular Landscape Unit. Characteristics of Landscape Units include: Average size of a raised field platform, average size of a raised field Neighborhood both by sum surface area as well as platform count, average distance between raised field Neighborhood and associated forest islands and permanent water networks, average size of a forest island, sum surface area of forest islands, sum count of forest islands, and the ratio of forest island area to Neighborhood platform area.

Landscape Unit Regional Distribution & Overlap

To interpret the regional landscape, each of the four types of Landscape Units (Figure 56) were combined with a raster calculator in ArcMap. An equation was created (1000(N) + 100(B) + 10(Ar) + 10(Ag). The variable N represents any cell value from the Neighborhood Landscape Unit Map. The variable B represents a corresponding cell value from the Buffer Landscape Unit Map. The variable AR represents the Archipelago Landscape Unit Map and the variable Ag represents the Agropolis Landscape Unit Map. Each of these rasters have the unclassified regions valued at 0. When the rasters are passed through the equation a four-digit number is returned indicating what types of Landscape Units are found in each cell. For instance, if all four of the Landscape Units overlap at one point on the landscape then the resulting raster cell for that location would be a value of 1234 (theoretically not possible). If only Agropolis Landscape

Units are identified in a location, then a 0004 is assigned to the raster cell. A combination of Agropolis, Neighborhood, and Archipelago Landscape Units would be returned as 1034. The combination of the four Landscape Unit Maps results in the Combined Landscape Unit Map (Figure 57). The purpose of the Combined Landscape Unit Map is to examine how the four different Landscape Units organize in comparison to one another and to what extent they overlap.

CHAPTER 5: RESULTS

Results for the project follow three general categories. The first is an analysis of the three landscape features used to rate the suitability of the landscape for different types of Landscape Units: raised field Neighborhoods, forest islands, and water networks. Landscape Units have different sets of criteria and a range of suitability allows for some interpretation as to the size and location of different Landscape Units across the landscape. Next, is an analysis of the four types of Landscape Units derived from the suitability maps themselves: Neighborhoods, Buffers, Archipelago, and Agropolis. These Landscape Units represent areas of the landscape that afford particular sets of tasks given the presence of a combination of landscape features. Last is an analysis of the ways in which Landscape Units overlap and abut one another across the landscape.

Raised Field Neighborhood Analysis

Based on a 40m proximity rule, 44,224 individual raised field platforms were organized into 4,444 individual raised field Neighborhoods (Figure 58). Digitized maps of these Neighborhoods were one of the building blocks for the four landscape units created in this project. The Neighborhoods have a combined total platform surface area of 120.3km^2. This figure represents only the elevated surfaces of the raised fields. If the canal areas within 20m of the platforms are also considered, then the area of the landscape associated with raised field farming increases to 387.8km^2. Table 1 lists the number of Neighborhoods that are created when the proximity rule is increased until the entire population of raised fields is collapsed into a single Neighborhood. The number of raised field Neighborhoods in west central Mojos is reduced from 4,444 to seven with a buffer of only 2,000m around polygons representing raised

field platforms. A buffer of 4,151m around all raised field platforms results in a single polygon with a total area of 7,050.4km^2. Buffering all raised field platforms 10km creates a single polygon 10,288 km^2 in size.

The average size of a Neighborhood by platform total surface area is 27,065m^2 (s = 142,402m^2) (Table 4). Neighborhoods range in size from 45m^2 to the largest Neighborhood of 4,967,767m^2. Of the 4,444 Neighborhoods identified, 3,360 have an individual total platform surface area less than 15,000m^2. The number of Neighborhoods of a given size decreases as the size of the Neighborhood increases (Figure 59). This is true when measuring Neighborhood size by the number (count) of platforms as well as surface area. Of the 4,444 Neighborhoods, 3,908 contain less than 10 platforms. Neighborhoods are found throughout the entire study area, however, the largest Neighborhoods with more than 300 platforms are all located in the northern portion of the study area along the Iruyañez river and north (Figure 58).

The average distance between a raised field Neighborhood and the nearest Neighborhood is 136m (s = 214m). Neighborhoods are most often found in groups with other Neighborhoods. Of the 4,444 Neighborhoods, only 47 had a distance to the nearest Neighborhood greater than 1,000m. Of those, only three had a near distance greater than 2,000m. The average distance from a Neighborhood to the nearest permanent flowing river is 7,455m^2 (s = 6,554m^2). Figure 60 compares the average distance of a Neighborhood from a river to the size (platform count) of the Neighborhood. Neighborhoods are consistently found at all distances from the river. Concentrations of fields are found within a km of the river as well as more than 20km away. This is true of large Neighborhoods with hundreds of platforms as well as small Neighborhoods with less than a dozen.

The average distance between a raised field Neighborhood and the nearest forest island is 1,252m (*s* = 1,140m). Figure 60 compares the distance from Neighborhood to nearest forest island to the size of the Neighborhood. No large Neighborhoods are found more than 2,500m from a forest island. Small Neighborhoods with fewer than a hundred platforms may be found as far as 7,500m from a forest island. While large Neighborhoods were constructed at great distances from the river, they were not being constructed at great distances from forest islands.

Forest Island Analysis

A total of 1,940 forest islands were mapped in west central Mojos. Forest islands represent the most habitable portions of the landscape and do not include the seasonally flooded gallery forests found along the permanent rivers. Also not included are rectangular patches of forest restricted to the elevated platforms of raised fields. The forest islands have a total combined area of 8,786ha (87.86km^2) of forest within the 10,281km^2 study area. In total forest islands represent just under 1% of the west central Mojos landscape. When examining the entire population of forest islands, the average size of a forest island is 4.5ha (*s* = 13.6ha). Forest islands range in size from 17m^2 or 0.0179ha to the largest of 318 ha. There is a decrease in the number of forest islands as the size of the forest island increases (Figure 61 & 62). Of the 1,940 forest islands, 1,558 are less than 4.84ha in size. Like Neighborhoods, maps of forest islands were used as a building block for the Landscape Units created as part of this project.

By area, forest islands less than 7.4ha in size make up 30.9% of the entire 8,786ha of forest island in the study area (Table 7). Another 30% of the forest islands are represented by islands ranging in size from 7.4 to 26.2ha. In total, roughly 61% of the forest islands in this study area are made up of smaller forests less than 26.2ha in size and have an average distance to

the nearest permanent river of more than 9,000m (Table 8). Figure 63 demonstrates the distribution of forest islands by size throughout the study area. This map highlights three areas of interest regarding large forest islands greater than 26.2ha in size. The first is a band of forests islands stretching from the western extent of the Omi through the Quinato wetlands and continuing northeast roughly midway between the Omi and Yacuma rivers. The second is a band of forest islands along the northern portion of the study area near a stagnant river or wetland known as the Tapado. This area appears similar in characteristics to the Quinato wetlands regarding the appearance of a large abandoned paleo river channel and the intersection of what appears to be many abandoned levees (covered with raised fields) and permanent wetlands. The third area is that of the Iruyañez river, which is the only permanent flowing river in the study with forest islands greater than 26.2 ha distributed along its banks.

The average distance between all forest islands is relatively small at only 546m (s = 686m) (Table 8). This average increases when measuring the distance between forest islands of larger sizes and other forest islands of the same size. For instance, the average distance between Rank 3 forests (>26.2 & < 66.6ha) jumps to 4,795m (s = 6,203m). Large forest islands appear to be more dispersed than the smaller forest islands, however, they are still visible in three bands or chains as shown in figure 55. Within the bands themselves the average distance between large forest islands is much lower along the Quinto wetland. When forest islands larger than 26.2 ha that are within 2km of the Quinato wetland are singled out, the average distance between forests drops to 1,660m (s = 1,544m). When the forest islands larger than 26.2 ha and within 2km of the Iruyañez are selected for analysis, the average distance between forest islands increases to 10,750m (s = 1,559m). The average distance from the largest forest islands (>26.2ha) to the nearest forest island of any size is 588.7m (s = 953.3m). While large forest islands are dispersed

from each other, they still have smaller islands scattered about in closer proximity. Large forest islands along the Quinato are clustered more tightly together than large forest islands along the Iruyañez river.

The average distance between a forest island and the nearest river is 7,878m (s = 7,188m) (Table 8). This measurement remains relatively consistent for all different size-ranks of forest islands. Both large and small forest islands can be found directly adjacent to the river as well as far off in the savanna at the midpoints between the rivers. Figure 54 compares the size of a forest island to its distance to a permanent flowing river.

The average distance from a Neighborhood to its closest forest island is also listed in Table 8. To create these statistics each raised field platform had its distance to the nearest forest island measured and its measurement assigned to that single forest island alone. Each forest island had all the measurements assigned to it averaged to determine the average distance to a Neighborhood. Of the 1,940 forest islands in the study area, 846 forest islands were identified as being the closest forest island to a raised field Neighborhood. These 846 forest islands are identified as 'Farming Forest Islands' in Tables 8, 9, 10 and Figure 53 and are the only forest islands to provide statistics for the near distances from forest island to Neighborhood. Of all the forest islands in the study area, Farming Forest Islands make up 54.1% or 4,755ha. Table 9 demonstrates how the average distance from a farming forest island to only those closest associated raised field is 330m (s = 439m) on average. Large forest islands also show stronger associations with raised field platforms given the larger average size of Farming Forest Islands compared to other forests.

Forest islands that were not the closest forest island to a Neighborhood are not necessarily completely unassociated with agriculture. In many instances raised field platforms are in close proximity of several forest islands. Farming Forest Islands can be found at great distances from the permanent rivers but the average distance between a raised field platform and its nearest forest is still only a few hundred meters (Table 10). There are some forest islands that are at great distances from raised field platforms, however, this is to be expected given the definition of west central Mojos which includes up to 10km of the area surrounding the raised fields themselves. With a 10km maximum distance, an average distance of 3,725m between 'other forest islands' and raised fields is still quite low.

The average distance of a Farming Forest Island to its associated Neighborhoods is also compared to the size of the forest island in Figure 62. There is a total of 60 forest islands greater than 26.2ha in size (Table 11). Among all these large forest islands, the greatest near distance to a Neighborhood is 2,541m. The average distance from the 32 Farming Forests within the set of 60 to the nearest Neighborhood is 788m (*s* = 651m) (Table 12). Only 23 Farming Forest Islands in the study area have a distance to the nearest Neighborhood greater than 2,541m. Of those 23 forest islands, only one is greater than 20 ha in size. Only two are greater than 2.6 ha in size. These results are consistent with the observation by Walker (2018: 76, 94, 101, 102) that large forest islands in west Central Mojos have strong associations with Neighborhoods of raised fields. There are a cluster of large forest islands near the boundary of west central Mojos between 8 – 10km from a raised field platform. Large forest islands are not restricted to west central Mojos, but those large forest islands near the core of the study are associated with raised field Neighborhoods.

All forest islands in the project were sorted into one of three groups. The smallest forest islands were used to identify Archipelago Landscape Units. The largest forest islands were used to identify Agropolis Landscape Units. All forests that were too large for the Archipelago Landscape Units and too small for the Agropolis Landscape Units are part of a third undefined group (Table 11). Archipelago forest islands are defined as being less than or equal to 0.8ha in size. Of all the forest islands in the study area, 3.6% fit the criteria for an Archipelago Landscape Unit. A total of 38.3% of all forest island surface area was identified as suitable for consideration as part of the Agropolis Landscape Unit Maps based on size alone. The remaining 59% (5,100ha) of forest islands do not fall into the criteria for Archipelago or Agropolis Landscape Units and were used only to identify Buffer Landscape Units. These 'undefined' forest islands are spread throughout the entire study area and overlap with Archipelago and Agropolis regions. Small forests are spread out amidst the larger forests as well as isolated by themselves in strings on the savanna several kilometers from a large forest island. It is interesting to note that of the 1,145 forest islands not associated with either Archipelago or Agropolis landscape units, 536 were the closest forest island to a raised field Neighborhood.

Permanent Flowing Rivers & Wetlands

There are five major Water Networks in west central Mojos that were of consideration to this project. There are four permanent flowing rivers that cut across the study area and a large permanent wetland known as the Quinato near its center (Figure 20). The Yacuma & Rapulo rivers to the south are much wider on average (65 – 70m) than the rivers to the north and also meander less on average. The Omi river, for example, is only 5m wide on average based on dry season imagery and changes direction much more often than the Yacuma or Rapulo. The length

of the rivers including meanders are measured through a 40km x 6km sample block to show how meanders can alter travel distance in the study area. The sample block was created by clipping out a long strip of the Iruyañez between its confluence with the Omi and another large confluence approx. 40km upstream to the southwest. The minimum bounding geometry tool produced a rectangle around this section of river 40km long by 6km wide. This polygon was adjusted to exact round dimensions 40km x 6km and then georeferenced over each of the four major rivers in the study area so that the river enters the sample box through the 6km leg to the southwest and exits the sample box at the opposite 6km leg to the northeast. This method demonstrates how the meanders in the rivers alter the length of the total river needed to pass through the entire sample block. A 40km strip of landscape along the Omi contains 104,881km of river. The same 40km length of landscape sampled on the Yacuma results in only 75,494km of river (Table 13). All four of the rivers originate outside the borders of the study area to the west and merge with the Mamore at the eastern side of west central Mojos.

The Quinato wetland does not have a permanent flow like the 4 main rivers although it is located along an abandoned paleo riverbed. Water does move in and out of the region, but not in a fashion that maintains a visible channel in the satellite imagery. These wetlands lie several thousand meters from the permanent flowing rivers and parallel them in an irregular shape from southwest to northeast through the study area. A similar wetland north of the Iruyañez, the Tapado, is also strongly associated with both large forest islands and Neighborhoods of raised fields. The Tapado also contains large numbers of raised field platforms with forests growing atop the platforms but not in the intervening canals. Though the Tapado was not used as a building block for Agropolis Landscape Units like the Quinato, future research could shed light on how comparable these two landscapes are.

Seasonal Streams

In total, 2,311km of seasonal streams were mapped for this study. This is by no means a representation of all the seasonal water networks that are present on the landscape. Preference was given to streams with clear connections to permanent flowing rivers with clearly established gallery forests. This allowed for a form of confirmation that the feature was indeed a stream. Streams in the study averaged less than 10m in width and were digitized with a single polyline down the center of the stream bed. Like the rivers, seasonal streams flow beyond the borders of the study area. Seasonal streams south of the Yacuma appear more like large wetlands as they expand in size across the savanna. These streams were digitized along their margins as polygons and then converted to centerlines to measure their distances. A total of 30.1km^2 of wetlands were included in the study. These wetlands are distinctly different from that of the Quinato wetlands in that they still link up with permanent flowing rivers and maintain clear channels of flow across the network. The Quinato wetland has more clearly established wetland vegetation across a much larger area.

Landscape Units

The next sections report the quantity and characteristics of different Landscape Units that were constructed from the above described datasets of Neighborhoods, forest islands, and Water Networks. Neighborhood Landscape Units were constructed from the locations of raised field Neighborhoods of any size. Buffer Landscape Units were constructed from the locations of both raised field Neighborhoods as well as forest islands of any size. Archipelago Landscape Units were constructed from the locations of raised field Neighborhoods, small forest islands less than

0.8ha in size, and seasonal streams. Agropolis Landscape Units were constructed from the locations of large raised field Neighborhoods, large forest islands, and the five Water Networks.

Neighborhood Landscape Units

Figure 44 shows the location of all Neighborhood Landscape Units identified in this project. Neighborhood Landscape Units were ultimately represented by any area of the landscape within 1 km of a raised field Neighborhood of any size. Of the 10,281km^2 study area, Neighborhood units covered 3,377.75km^2. This represents roughly 33% of the total study area (Table 14). These landscape units include all raised field Neighborhoods of any size. The Neighborhood Landscape Units include all 120.3km^2 of raised field platforms in the study with a ratio of 0.035m^2 of platform per square meter of landscape unit.

To help identify Archipelago and Agropolis Landscape Units, Neighborhood Suitability Maps 3 & 4 were created to identify areas of the landscape associated with large as well as small raised field Neighborhoods (Figures 30 & 32). Neighborhood Suitability Map 4 represents areas of the landscape most associated with the tasks required to build and maintain small raised field Neighborhoods. Small Neighborhoods were defined as any area within 2km of a raised field Neighborhood with a platform count less than 98. To create a landscape suitability, map the 2km unit was further subdivided into two 1km zones and assigned suitability rankings. A total of 4,387 small raised field Neighborhoods with a platform count less than 98 were identified. Rank 1 suitability zones within 1km of a small raised field Neighborhood totaled 3,326.8km^2. Rank 2 suitability zones within 1 to 2km^2 of small raised field Neighborhood totaled 1,739.8km^2. Rank 1 and 2 suitability zones combine to make a total of 5,066.5km^2 of west central Mojos landscape. The areas of the landscape associated with small Neighborhoods also overlap with areas

associated with large Neighborhoods and are found in all regions of the study area where raised fields are found. There are no areas of the landscape where large Neighborhoods are being constructed that small Neighborhoods are not also found.

Neighborhood Suitability Map 3 outlines areas of the landscape within 2km of a large raised field Neighborhood (Figures 29 & 30). A total of 57 raised field Neighborhoods with a platform count of 98 fields or greater were identified. The Rank 1 suitability zones within 1km of a large raised field Neighborhood totaled 604.4km^2. Rank 2 suitability zones within 1 to 2 km of a large raised field Neighborhood totaled 549.3km^2. Rank 1 and 2 suitability zones combine to make a total of 1,153.7km^2 of landscape associated with large field Neighborhoods. Large Neighborhoods can be found along each of the permanent flowing rivers and major wetlands identified in the study as well as several km away from the rivers into the savanna (Figure 30). They are most expansive at the confluence of the Iruyañez and Omi rivers with a near continuous sprawl of fields out into the savannas to the north. Moving south and west from the confluence, Large Neighborhood are scattered into isolated units with several kilometers of landscape separating them.

Buffer Landscape Units

Buffer Landscape Units are defined as any of the area of the landscape that is associated with forest islands or raised field Neighborhoods. Buffer Landscape Units were selected based on an interpretation of the Buffer Combined Suitability Map (Figure 46). Buffer Landscape Units for this project have a combined distance of at least 3 km to the nearest forest island & raised field Neighborhood. The Landscape Units do not include any areas of the landscape within 1 km of a raised field Neighborhood or forest island. Figure 47 shows the location of all

Buffer Landscape Units identified in this project. In total, 4,944km^2 of Buffer Landscape Units were identified (Table 14). The Landscape Units are not continuous and are divided into 167 different portions. The outer portions of the study area contain the most dense and continuous sections of Buffer Landscape Units which is to be expected given the definition of a Buffer Landscape Unit itself. These outer Landscape Units are quite extensive and cut by numerous chains of forest islands passing the north, west, and south sides of the study areas. Of the 4,944km^2 of Buffer Landscape Units, 4,210km^2 can be associated with the outer 1km band of the study area. Figure 64 shows the 734 km^2 of Buffer Landscape Units in the project that did not intersect with the outer 1km band of the study area. This map more clearly highlights a dense area of Buffer Landscape Units near the center of the region that are completely surrounded by raised field Neighborhoods. These Buffer Landscape Units are different from the other units in that they are separated from areas outside the study area by raised field Neighborhoods. The savanna in the center of the study area appears to be dominated by Buffer Landscape Units; however, they are not continuous and are dotted or fragmented in several locations by the passing of chains of forest islands. If the mobility of a Mojos farmer is thought to extend beyond a 2km walk, then these Buffer Landscape Units would decrease in size and become more fragmented, however, the Landscape Units at the center of the study aera would still be surrounded on all sides by raised field Neighborhoods distinguishing them from Landscape Units along the border of the study area.

Buffer Landscape Units intersect with the Iruyañez and Omi rivers in only 9 locations (Figure 65). This is a significant decrease when compared to the intersection of Buffer Landscape Units with the Yacuma and Rapulo rivers which are quite extensive. There are a series of Buffer Landscape Units near the confluence of the Iruyañez and Omi rivers that could

be significant in delineating between different Agropolis Landscape Units identified in this area (discussed below). The intersection of Buffer Landscape Units midway down the Omi river coincides with a change of dominant pattern in field orientation identified by Lee (2017).

Archipelago Landscape Units

Archipelago Landscape Units were ultimately represented by any area of the landscape that met three sets of criteria: located within 1 km of a seasonal stream, within 2 km of a small raised field Neighborhood containing less than 90 individual platforms, and within 2 km of a small forest island less than or equal to 0.8ha in size. Archipelago Landscape Units represent areas of the landscape associated with less intensive forms of agriculture as well as smaller permanent settlements. Activities in these portions of the landscape included fishing and long-distance travel as well as farming.

Of the 1,940 forest islands in the study, 735 met the size criteria for an Archipelago Landscape Unit. The average distance from a small Archipelago forest island to the nearest permanent river is 6,588m (s = 5,260m) (Table 12). Archipelago forest islands are found both along the four primary rivers as well as scattered across the surrounding savanna and continue outside the designated study area for this project. Of the 735 small Archipelago forest islands, only 278 were identified as the forest island closest to a raised field Neighborhood and designated a 'Farming Forest Island' Several hundred small forest islands are found in chains along seasonal streams that are not associated directly with raised field Neighborhoods. However, Archipelago Landscape Units in this project only included portions of the landscape with small forest islands in combination with small raised field Neighborhoods (platform count < 97) as well as seasonal streams.

In total, 1,368km^2 of Archipelago Landscape Units were identified. This represents 13.3% of the total study area (Table 14). A total of 109 individual Archipelago Landscape Units were defined (Figure 51). The average size of an Archipelago Landscape Unit is 12.4km^2 (s = 11.9km^2). Archipelago Landscape Units contain on average 318,999m^2 (s = 631,426m^2) of raised field platform surface area (Table 15). This is significantly less than the Agropolis Landscape Units with more than 2km^2 per unit. On average 0.02% of the total area of an Archipelago Landscape Unit is represented by raised field Neighborhoods (Table 16).

. Within Archipelago Landscape Units, farmers are not travelling any further to tend their fields than they would within an Agropolis Landscape Unit (Table 17). However, Neighborhoods within Archipelago Landscape Units can be more than 10km from a permanent river. This demonstrates how Archipelago Landscape Units can be located near the permanent rivers where they meet with smaller streams or further out int the savanna where seasonal streams are found far from the permanent rivers.

The average total forest cover within an archipelago unit is 226,872m^2 (s = 389,632m^2) with an average of 8.1 (s = 7.8) individual forest islands per Landscape Unit (Table 18). The average ratio of total forest island area to Neighborhood area is 3.4 (s = 13.3) (Table 16). The ratio of the average size of an individual forest island to the average size of an individual Neighborhood is 1.0 (s = 2.1). These numbers demonstrate the significant decrease in the total surface are of raised field Neighborhoods encountered in Archipelago communities compared to Agropolis communities. Despite containing far less forests, Archipelago communities have higher ratios of forests to Neighborhoods except when comparing individual forest size to

individual platform size. Large forests are associate with large Neighborhoods but are not automatically associated with larger individual platforms.

The average distance from a small Archipelago forest island to the closest raised field Neighborhood is 693m (s = 532m) when considering Farming Forest Islands alone (Table 19). This is higher than the average walking distance for large Agropolis forest islands, 271 (s = 170), discussed below. This is consistent with the observation that larger forest islands are more strongly associated with raised field neighborhoods than smaller forest islands. The average distance from an archipelago forest island to the nearest permanent river is also higher than that for the Agropolis Landscape Units with an average of 5,762m (s = 5,354m) (Table 19). Small forest islands are found along the river within close proximity of large forest islands; however, the majority of the small forest islands are found further out in the savanna scattered along seasonal streams.

When examining the average size of a raised field Neighborhood within an Archipelago Landscape Unit, it was found that Archipelago Landscape Units near the confluence of the Omi and Iruyañez are more likely to have large raised field Neighborhoods than any other area (Figure 66). Figure 67 demonstrates the opposite pattern when examining the average size of an individual platform rather than an entire raised field Neighborhood. Moving south through the study area larger field platforms are found in Archipelago Landscape Units with the smallest platforms consistently being constructed north of the Iruyañez (Figure 59). A similar pattern is found regarding the total surface area of forest islands found within Archipelago Landscape Units. The largest number of Archipelago Landscape Units with more than 0.5 km^2 of forest islands within their boundaries are located along the Tapado area along the northern border of

the study area (Figure 68). Figure 69 demonstrates how this same area along the Tapado contain the only Archipelago Landscape Units that do not link back up with a permanent flowing river. South of the Iruyañez, only 10 Archipelago Landscape Units were not found to connect back up with a primary river system. The nature of digitizing seasonal streams favored streams proven to link with the major river network, however, raised field Neighborhoods had no such criteria.

Agropolis Landscape Units

Agropolis Landscape Units were ultimately represented by any area of the landscape meeting three sets of criteria: located within 4km of a permanent flowing river or major wetland system, within 4km of a large forest island greater than or equal to 26.4ha in size, and within 2 km of a large raised field Neighborhood containing at least 98 or more raised field platforms. These portions of the landscape are those most strongly associated with intensive forms of agriculture, large permanent occupations, and trade or transportation over permanent river networks.

Of the 1,940 forest islands in the study, 60 fit the criteria for an Agropolis Landscape Unit regarding size of the forest island alone. Of these 60, forest islands along the Tapado represent the only area containing a significant number of large forest islands that are found at several thousand meters from either a permanent river or the Quinato wetland. Northeast of the Quinato a band of forest islands extend beyond the mapped boundary of the Quinato also (Figure 63). Only three forest islands large enough to be considered part of an Agropolis Landscape Unit can be found south of the Quinato. After applying the criteria of proximity to a permanent river or the Quinato as well as the criteria of being in proximity of large raised field

Neighborhoods, only 7 large forest islands were identified and confirmed to meet all three criteria for consideration as part of an Agropolis Landscape Unit.

Figure 49 shows the location of the most suitable Agropolis Landscape Units surrounding the 7 identified Agropolis forest islands. Note that the two Landscape Units furthest west are associated with a single Agropolis forest island and were combined and considered a single multi-part Unit. Referring to the Agropolis Suitability Map (Figure 53), it is important to remember that the Agropolis Landscape Units are an interpretation of the Combined Suitability Map which provides a range of possible distributions. The area separating the multi-part Landscape Unit is not necessarily unassociated with an Agropolis, however, its level of association is decreased given the proximity based ranking system used by the project. This multi-part Landscape Unit highlights the mobility afforded raised field farmers given the mosaic of landscape features available.

A total of 183km^2 of Agropolis Landscape Units were identified for this project (Table 14). The average size of an Agropolis Landscape Unit is 26.1km^2 (s = 26.9km^2). The average sum coverage of raised field Neighborhoods within an Agropolis Landscape Unit is 2.1km^2 (s = 2.7km^2), nearly 7 times that of the archipelago units (Table 8a). Despite being comprised of significantly larger forest islands by definition, the Agropolis Landscape Units have a lower ratio of forest island surface area to Neighborhood surface area given how much more expansive Neighborhood Landscape Units are within the Agropolis Landscape Units (Table 16). This is significant considering that the criteria for Agropolis Landscape Units included buffers up to 4km wide compared to just 2km for Archipelago Units. More landscape and larger forests are included in the Agropolis Landscape Units by definition, however, they still maintain a lower

ratio of sum forest island surface area to sum Neighborhood platform surface area given the exponential increase in the amount of Neighborhood surface area per Landscape Unit.

The average size of an individual raised field platform within an Agropolis Landscape Unit is 3,112m^2 (Table 15). This is relatively similar to that of the Archipelago Landscape Units (3,244m (*s* = 1,216m)) and not significantly higher than the average for all 44,224 raised fields (2,445m (*s* = 2,014m)) Agropolis Landscape Units contain larger concentrations of fields; however, they do not contain larger individual platforms on average. Farmers in Archipelago Landscape Units still constructed platforms of the same size if not larger than those found in Agropolis Landscape Units. The closest forest island (Farming Forest Island) to each of the raised field platforms was identified. The average distance from all farming forest islands within Agropolis Landscape Units to all the raised fields associated with each farming forest island is 924m (*s* = 279m) (Table 17). This is slightly higher than that of the Archipelago Landscape Units (697m) but this is expected given that Agropolis Landscape Units contain much larger Neighborhoods on average. Fields in bigger Neighborhoods span greater distances away from the forest islands creating a higher range of values to include in the calculations. When examining the average distance to only the nearest Neighborhood, forest islands within Agropolis Landscape Units have a much shorter average walking distance than Archipelago Units (Table 19). However, this does not take into account the fact that those Neighborhoods may extend for more than a kilometer away from the Agropolis and require a greater amount of traveling to tend to each field (Table 16) In general, there is not a significant difference between the distances that farmers walk between their fields when comparing Agropolis and Archipelago Landscape Units to each other except that within Archipelago landscape units there is a slightly larger minimum walking distance to reach the first field in the Landscape Unit.

Agropolis Landscape Units show a significant increase (0.2 to 0.7km^2) in the sum forest island surface area found within each Unit when compared to the Archipelago Landscape Units (Table 18). The average number of forest islands within each Unit only increases from 8.1 to 9.8 between Archipelago and Agropolis Landscape Units, however, the average size of an individual forest island increases from 0.02 to 0.13km^2 as is expected. The ratio of Average forest island surface area to raised field Neighborhood area significantly drops from the Archipelago to Agropolis Landscape Units also (1.0 to 0.2) indicating the increase in the surface area of raised field Neighborhoods is much greater than that of the increase in available forest island area (Table 16).

There are few enough Agropolis Landscape Units identified to list them individually (Tables 20, 21, & 22). Agropolis Landscape Units 1,2 and 7 (Cerro, San Juan & Miraflores), represent the largest and most continuous units identified, each being at least 3 times larger than the other units (Figure 70; Table 20). These three Landscape Units are also distinguishable given their total number of intersecting raised field Neighborhoods (Figure 71). However, these units are different from each other in several ways. Twice as much forest island area is found in Landscape Agropolis Unit 7 (Miraflores) compared to that of Agropolis Landscape Unit 1 (El Cerro), although El Cerro is one of the largest forest islands in the dataset (Figure 72 & 73; Table 21). El Cerro forest island has a greater average distance between itself and the nearest forest islands leaving it isolated relative to other forest islands, especially large forest islands. San Juan, though relatively close to El Cerro has 13 other forest islands within the same unit whereas Cerro only has one other forest island in close proximity. The average distance between forest islands within the Agropolis Landscape Units also shows a pattern of increased forest island proximity in the Miraflores region compared to the landscapes around El Cerro and San Juan.

A significant difference between the Agropolis Landscape Units along the Quinato is their increased distance from a permanent river (Figure 74; Table 22). Also as previously noted, the raised field Neighborhoods in these regions have different average sizes to their platforms. Raised field platforms in the Cerro Agropolis Units have an average size of 1,494m^2 (s = 1,325m^2) despite having neighborhoods with more than 100 fields per neighborhood. This is a clear difference from the San Juan Agropolis Unit with an average platform size of 3,142m^2 (s = 2,396m^2) (Table 22).

Unit Organization & Overlap

This section examines the ways that different Landscape Units are organized in relation to one another and more specifically how they overlap or abut one another.

Agropolis & Neighborhoods

Agropolis Landscape Units are comprised completely of Neighborhood Landscape Units (Figure 75). This means that any area of the Agropolis Landscape Unit is within 1 km of a raised field Neighborhood of any size. Agropolis Landscape Units are also surrounded by networks of Neighborhood Landscape Units that extend in both directions along the nearest water source as well as out into the surrounding savanna. Neighborhood Landscape Units seem to flow from Agropolis to Agropolis Landscape Unit following permanent and seasonal stream networks. The only exceptions are small areas of the permanent rivers absent of raised field Neighborhoods. These locations coincide with the sections of Buffer Landscape Units that intersect with the rivers as noted above (Figure 65).

Archipelagos & Neighborhoods

Of the 1,368km^2 of landscape that make up Archipelago Landscape Units, 977.63km^2 intersect directly with Neighborhood Landscape Units (Table 23). More than 70% of Archipelago Landscape Units intersect directly with a Neighborhood Landscape Unit. The remaining portions of Archipelago Landscape Units that do not intersect with Neighborhood Landscape Units directly still abut or border a Neighborhood Landscape Unit. The extent of Neighborhood Landscape Units north of the Iruyañez river results in Archipelago Landscape Units being completely surrounded by Neighborhood Landscape Units. Moving south from the Iruyañez, Neighborhood Landscape Units become more restricted to the intersection areas with the Archipelago Landscape Units. With a distribution of near continuous Neighborhood Landscape Units, it becomes difficult to discern where one Landscape Unit ends, and another begins (Figure 76).

Agropolis & Buffers

The average overlap between an Agropolis landscape unit and a buffer unit is 0.73km^2 (s = 0.84km^2) (Figure 77; Table 24). Of the 183km^2 of Agropolis Landscape Units identified, only 4.8% intersected with Buffer Landscape Units. This low average is expected given that Buffer Landscape Units should only exist on the margins of raised field Neighborhoods and Agropolis Landscape Units are comprised entirely of raised field Neighborhoods. Figure 69 shows the location of Agropolis Landscape Units in relation to Buffer Landscape Units. While Buffer Landscape Units commonly intersect regions along the Yacuma and Rapulo rivers (Figure 65), north of the Yacuma the buffers are more clearly restricted to the savanna areas adjacent to the rivers. The Buffer Landscape Units intersect with the Iruyañez river in only 7 locations. Each of

these locations is located between an Agropolis Landscape Unit and may reflect some form of organized separation between the Landscape Units. There is only one intersection of the Buffer Landscape units with the Omi north of the Quinato region. This buffer along the Omi corresponds to the transition between raised field platforms of different orientation patterns identified by Lee (2017).

Archipelagos & Buffers

Archipelago Landscape Units have an average overlap of 2.56km^2 (s = 6.79km^2) with Buffer Landscape Units (Table 24). Of the 1,368km^2 of Archipelago Landscape Units identified, 11.6% (159km^2) overlap with the Buffer Landscape Units. The overlap between Landscape Units is more significant in the southern portion of the study area where raised field Neighborhoods are less prevalent. Figure 70 shows how Archipelago Landscape Units north of the Iruyañez river are more abundant than Buffer Landscape Units and are separated from Buffer Landscape Units by large regions of raised field Neighborhoods. In the north Archipelago Landscape Units surround small Buffer Landscape Units and are isolated from them by raised field Neighborhoods. Moving south, Archipelago units intersect more often with Buffer Landscape Units and are generally surrounded by Buffer Landscape Units rather than isolated from them (Figure 78 & 79). Buffer Landscape Units do not pass entirely through Archipelago Landscape Units but consistently intersect them along their borders and may represent the capacity of the Archipelago Landscape Unit to cut across the landscape splitting larger buffer zones into smaller units.

Agropolis & Archipelagos

Of the 7 Agropolis landscape units identified, 6 intersect with at least one Archipelago Landscape Unit (Figure 80). The Agropolis Landscape Unit associated with the forest island of San Juan is cut across its center with an Archipelago Landscape Unit as a result of the numerous small forest islands in close proximity to the Agropolis Landscape Unit center. The connection of Agropolis & Archipelago Landscape Units also highlights more possible divisions between different Agropolis Landscape Units. The dense network of field Neighborhoods near San Juan & Cerro make distinguishing between the two landscapes difficult without examining the individual statistics of the raised field platforms being constructed across this region. Raised field Neighborhoods north of the San Juan landscape decrease significantly in average size of field platform, possibly being a result of different size of social units operating in this region. Both the Cerro and San Juan Agropolis Landscape Units have associated Archipelago Landscape Units linking them with the savannas on both sides of the river.

Each of the remaining Agropolis Landscape Units along the Iruyañez river are connected to Archipelago Landscape Units that stretch several kilometers out into the savanna. The Agropolis Landscape Unit of Miraflores in the Quinato wetland is the only Agropolis Landscape Unit found in the savanna several kilometers from a permanent flowing river. This Landscape Unit is linked back up with the surrounding savannas by a series of Archipelago Landscape Units that stretch almost entirely back to the permanent river systems. At first Miraflores appears isolated given its distance from the permanent flowing rivers. However, when Miraflores is considered with its connecting Archipelago Landscape Units, it no longer appears isolated from the main river but is rather part of a seasonal network spanning the distance between the rivers.

Unidentified Landscape Units

Of the 10,281km^{2}of study area, a total of 9,873km^2 were assigned to the four types of Landscape Units. Considering the overlap that takes place between different units, the final map of all combined Landscape Units (Figure 57) contained 1,736km^2 of undefined Landscape Units that were not assigned to any of the four available types, including Buffer Landscape Units. These units are the result of the 1,145 forest islands that were too large for consideration as part of an Archipelago Landscape Unit and too small for consideration as part of an Agropolis Landscape Unit (Figure 81). If the definition of an Archipelago Landscape Unit were changed to include slightly larger forest islands, then the result would be an increase in the length of the Archipelago Landscape Units along the seasonal streams they already occupy. In contrast, changing the definition of an Agropolis Landscape Unit to include slightly smaller forest islands would not have the same effect of increasing the size and abundance of the Landscape Units. Agropolis Landscape Units are still restricted by the location of large raised field Neighborhoods that are not as abundant as the smaller raised field Neighborhoods used to identify Archipelago Landscape Units. Undefined Landscape Units will still occur naturally towards the borders of the study area as these locations are by their own definition approaching 10km distance from the nearest raised field Neighborhood. Another type of Landscape Unit that represents forest islands without raised field Neighborhoods is required to assign 100% of the landscape to a Landscape Unit.

CHAPTER 6: DISCUSSION

The purpose of this project was to use a landscape approach to interpret the settlement patterns of pre-Columbian raised field farmers in west central Mojos. The pre-Columbian landscape was reconstructed by mapping the distribution of three types of landscape features: forest islands, raised agricultural fields and water systems (rivers, streams & wetlands). Walker (2018) identified four types of patterned clustering or 'constellations' of these landscape features in west central Mojos. These constellations and the immediate area of the landscape that surrounds them are referred to here as Landscape Units. Each of the four types of constellations or Landscape Units represent a landscape that afforded its inhabitants a specific set of community tasks associated with that particular cluster of landscape features. For example, areas with numerous raised fields as well as permanent rivers afforded inhabitants a wide range of tasks related to both farming on raised fields as well as trade and transportation along permanent rivers. While carrying out these tasks members of a community moved between forest island, raised field, and river. All the while, they experienced larger portions of the landscape than just the platforms of raised fields or the interiors of forest islands. The mapping of Landscape Units provides insights into how different communities were distributed across the landscape and how they went about interacting with one another. It was hypothesized that Landscape Units would demonstrate an integration of river and savanna settlements into a larger interconnected subsistence system rather than isolated regions without interaction.

The mapping of Landscape Units in west central Mojos highlights two distinct regions regarding the integration of river and savanna portions of the landscape. Both of these regions demonstrate an integration of remote savanna locations with permanent river networks. The first

region is highlighted by the arrangement of Agropolis Landscape Units at intervals along the Iruyañez river and the second by the arrangement of Agropolis Landscape Units along the Quinato wetland at great distances from permanent rivers (Figure 82). These two regions, north and south, are similar in that they both incorporate large portions of the landscape by the organization of Archipelago & Neighborhood Landscape Units around a series of Agropolis Landscape Units. They are, however, distinct from each other in several ways.

Along the Iruyañez, Agropolis Landscape Units are organized along the permanent river networks with large forest islands being located never more than 2km from the edge of the river. In each instance, Agropolis Landscape Units intersect with Archipelago Landscape Units which extend several thousand meters out into the surrounding savanna (Figures 83 & 84). Portions of the savanna separating the Iruyañez from the Omi and Tapado rivers are spanned completely by Archipelago and Neighborhood Landscape units allowing for interactions to take place between the different river systems upstream of their confluences.

Along the Quinato wetland to the south, another region is highlighted incorporating the portions of the landscapes between the rivers. Agropolis Landscape Units along the Quinato are several thousand meters from both the Omi and Yacuma rivers (Figure 85). In the southern region, Agropolis Landscape Units are still surrounded by a network of Archipelago & Neighborhood Landscape Units, just as they were in the north along the Iruyañez river. However, the Quinato wetlands do not emphasize the permanent river as the center of the region but rather emphasis the area between the two rivers. By associating Agropolis, Archipelago & Neighborhood Landscape Units, connections may be made between areas along the upper Omi with areas along the Yacuma despite the fact that these two rivers never merge before joining the Mamore river to the east.

These two regions are also distinguishable from each other based on the size and extent of Neighborhood Landscape Units themselves. As noted in previous research, raised field Neighborhoods are much more extensive near the confluences of the Iruyañez and Omi Rivers with a near continuous distribution of fields extending out into the savannas to the north (Garcia-Cosme 2015, Lee 2017). In the northern region along the Iruyañez, Neighborhood units clearly dominate the landscape. Almost all Archipelago Landscape Units are completely surrounded by Neighborhood Landscape Units (Figure 76). In this northern region farming is taking place at greater distances from the Archipelagos and their established stream networks. In contrast the Neighborhood Landscape Units in the southern region are in many cases entirely restricted to the regions identified as Archipelago or Agropolis Landscape Units. In the southern region farmers are not traveling as far from water networks and small forest islands to construct and tend raised field Neighborhoods. The largest Neighborhoods are concentrated near the intersection of the Iruyañez and Omi rivers (Figure 66). However, the smallest raised field platforms are consistently constructed north of El Cerro along the Iruyañez river while the largest platforms are found further south (Figure 67).

A northern and southern region is also distinguishable based on the organization of large forest islands within each region. As already noted, along the Iruyañez large forest islands are spaced out along the banks of the river with an average of 10,750m (s = 1,559m) separating them. There are 695 ha of forest island spread along the banks of the Iruyañez (Figure 86). The Iruyañez crosses an area more than 90km in length. In contrast, there are concentrations of large forest islands with less than a kilometer separating them along the margins of the Quinato wetland (Figure 87). The 866 ha of forest island found along the margins of the Quinato wetland are clustered within an area no more than 45km in length from southwest to northeast. In an area

half the size as the Iruyañez, the Quinato wetland contains slightly more forest island surface area with significantly increased clustering of the largest forest islands.

The northern and southern region are also distinguishable from one another based on the known distribution of ring ditches in west central Mojos (Figure 88). To date there have been no ring ditches identified north of the Quinato wetland in west central Mojos, however, ring ditches are present in eastern Mojos as well as other locations along the southern rim of Amazonia (Walker 2008; De Souza et al. 2018). Ring ditches in west central Mojos have been reliably dated to the Cerro phase of west central Mojos (Cal CE 1200-1500) (Walker 2018:51).

These two regions are also distinguishable based on the transitional zone between them. This transitional zone can be identified by the large concentration of Buffer Landscape Units that are surrounded on all sides by Neighborhood Landscape Units (Figures 89 & 90). The transitional zone stands out from the surrounding Neighborhoods, especially considering that the study area itself is defined by the presence of raised field Neighborhoods. The Omi river which runs through the center of this transitional zone is clearly absent of any large forest islands though it does have a near continuous distribution of raised field Neighborhoods and smaller forest islands. There are no forest islands greater than 23 hectares along this strip of the Omi and the average size of a forest island in this area is only 4.2ha (*s*= 5.5ha). A very narrow strip of Buffer Landscape Units connects with the Omi river near the center of this transitional zone (Figure 91).

This connection of the Buffer Landscape Unit with the permanent river is the only one on the Omi in this central region and it coincides with a transition in other patterns previously identified. First, this strip of the Omi has been identified as a transitional zone in the organization of raised field Neighborhoods into oriented groups (Lee 2017). North of the

transitional zone fields are dominated by a pattern of organization that oriented fields to a North/East cardinal direction. South of the transitional zone raised field platforms are more commonly oriented to a Northeast/Southeast cardinal direction (Figure 92). This transitional zone also coincides with the estimated transition between the territories of the Cayuvava & Movima Language groups as outlined by Denevan (1966).

While it is concluded here that two distinct settlement patterns are present in west central Mojos, it is important to note that these two patterns are not necessarily exclusive of one another. Their defining Landscape Units are constructed from the same constellations of landscape features even if the Landscape Units are organized differently in relation to one another. The Buffer Landscape Units that separate these two regions are crossed by chains of forest islands that are not associated with raised field Neighborhoods. Buffer Landscape Units become far less prominent in the landscape when the mobility of a raised field farmer is pushed out beyond 2km from a Neighborhood or forest island. The term buffer may be inappropriate for this central portion of the landscape as it implies an area of less activity and therefore less interaction between communities. Rather, these Buffer Landscape Units at the center of west central Mojos may be better explained by a different set of land management tasks that may have been taking place. For example, ongoing mapping efforts in west central Mojos are finding large numbers of permanent fish weirs in updated satellite imagery of the region (Figure 93). The current distribution of these weirs overlaps with the transitional zone identified here. Future research should consider the relationships that permanent fish weirs have with the transitional zone and the agricultural fields that surround the zone in every direction. The increased availability and accuracy of digital elevation models in the region should be utilized to map the movement of people, water and possibly fish species through the pre-Columbian landscape.

APPENDIX A: FIGURES

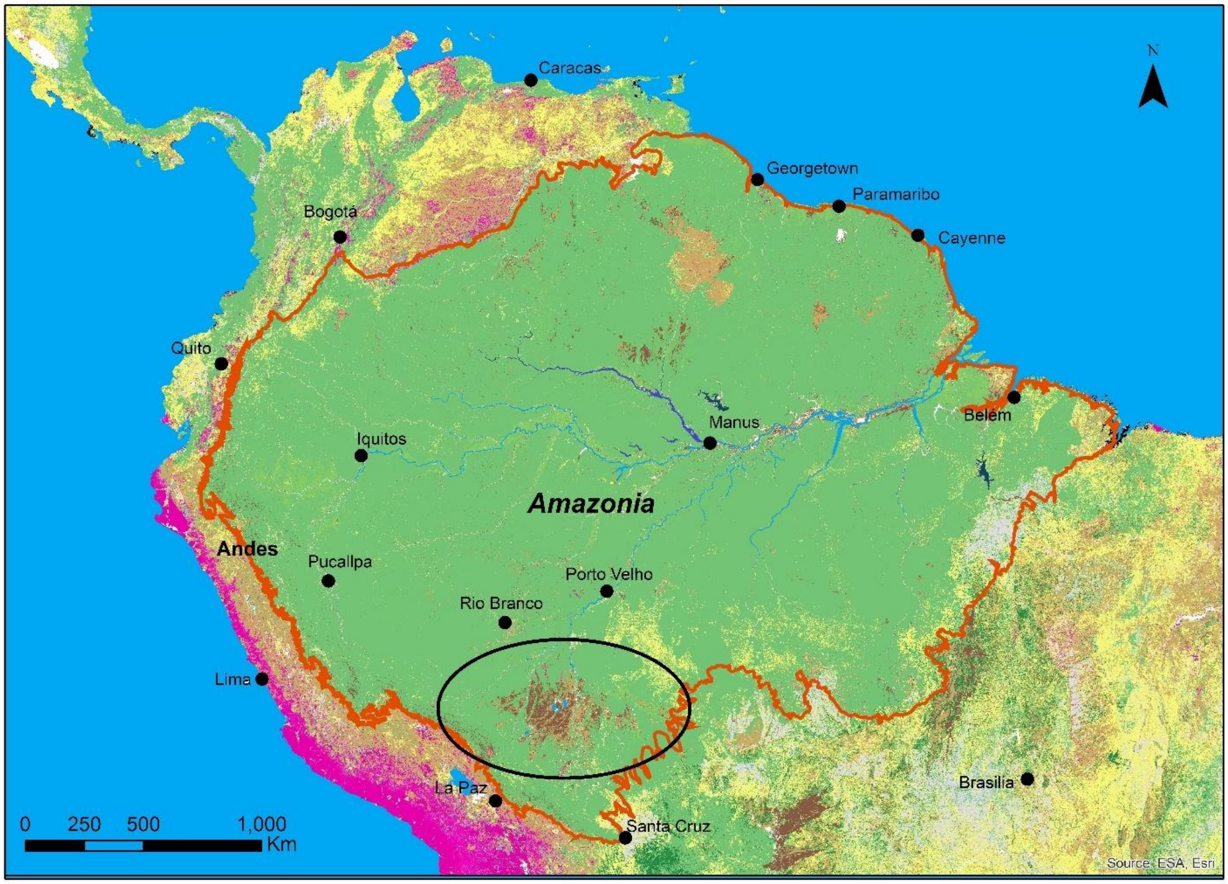


Figure 1*:* The boundary of Amazonia as defined by the World Wildlife Fund is shown in red atop an Esri Global Land Cover map. The floodplains of the Llanos de Mojos, circled, stand out in stark contrast to the tropical forests that surround them.

Figure 2: (Left) The llanos de Mojos makes up a majority of the department of the Beni, Bolivia. Its seasonal savannas stand out against the tropical rainforests of Amazonia that surround it. The landscapes of west central Mojos, marked with a dotted line, has a long history that includes several thousand years of interaction between communities and the environment. **(Right)** Within west central Mojos, savanna is the dominant vegetation pattern. Forest cover is scattered in isolated patches across the savanna or restricted to the seasonally flooded banks of the permanent rivers and lakes.

Figure 3: A seasonal stream passes by Santa Maria forest island as it meanders into the surrounding savanna. The gallery forests along the stream are easy to distinguish from the ciruclar to irregular shaped forest islands. (photograph by author)

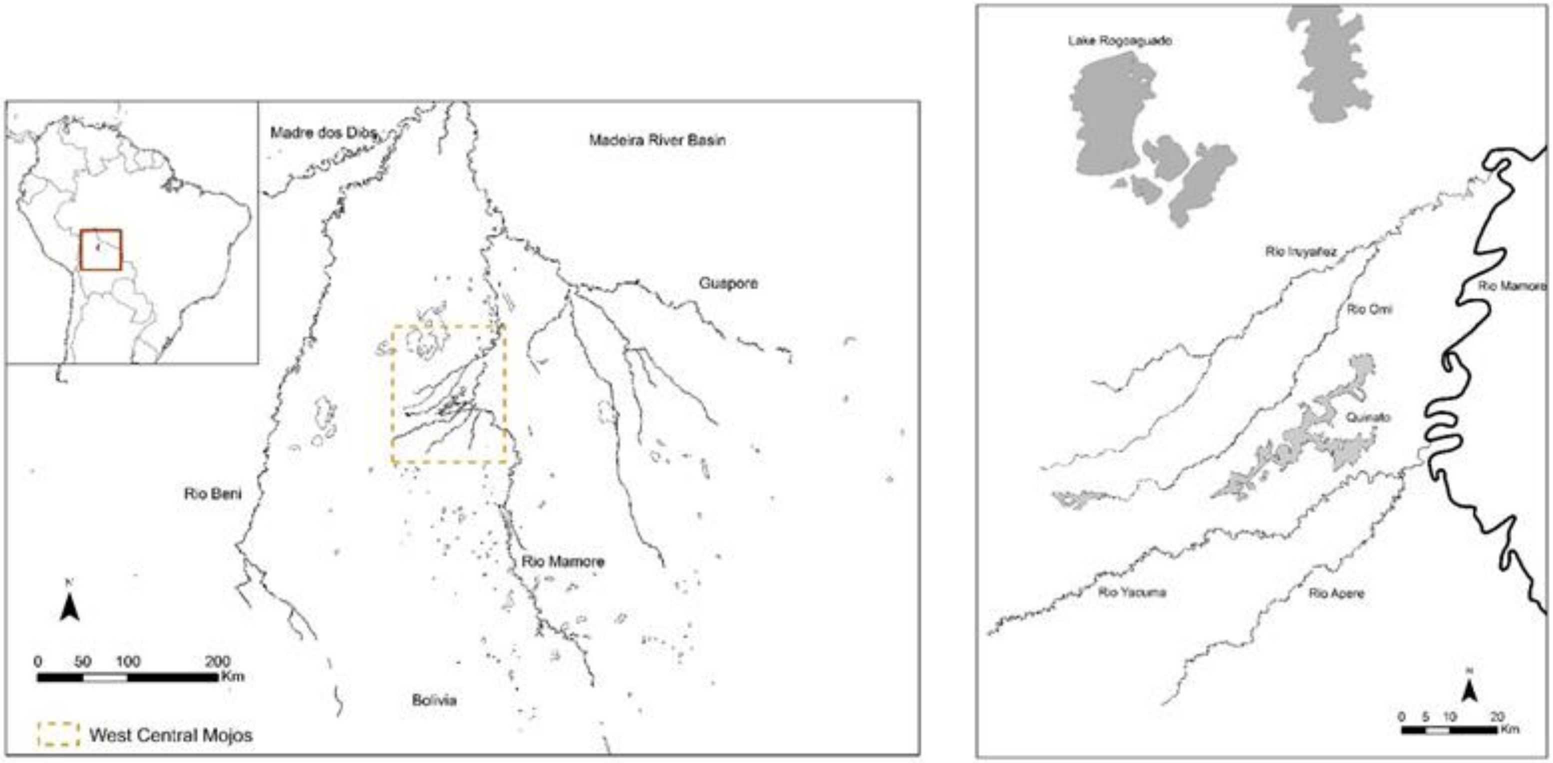


Figure 4: (Left) The llanos de Mojos is located in the Bolivian department of the Beni within the Madeira River basin. **(Right)** West central Mojos is located near the center of the region on the western side of the Mamore river. It is crossed from southwest to northeast by a series of permanent rivers that flow into the Mamore.

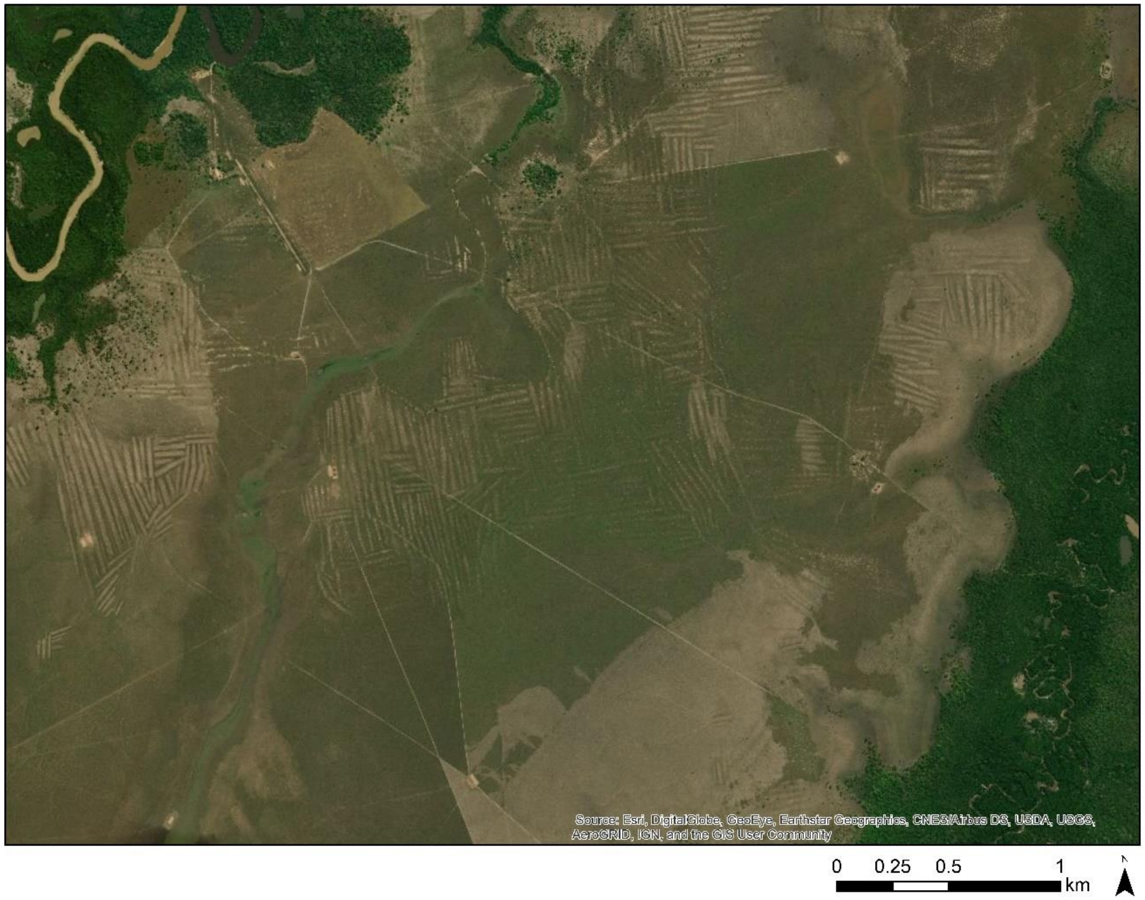


Figure 5: Large raised field platforms are scattered across the west central Mojos savannas. Though difficult to see from the ground, they can be identified and mapped from aerial photographs and satellite imagery.

Figure 6: Raised field platforms are difficult to identify from the ground even for someone familiar with their location from satellite imagery. **(Left)** In this photo taken at Miraflores forest island in the Quinato wetland, the photographer is standing on one raied field platform while a research team stands on an adjacent platform. Water in the intervening canal prevents walking between the fields. **(Right)** The same raised fields are photographed with a drone. The locations of the photographer and survey team in the first image are shown. (Photographs by author)

Figure 7: Digitizing raised agricultural fields from satellite imagery and then transferring them from Google Earth to ArcMap: **(Top)** A group of raised fields are identified in an image on Google Earth. **(Middle)** The raised field platforms are digitized with polygons marking their borders. **(Bottom)** The polygons are transferred to ArcMap as a form of vector data that can be used for further analysis.

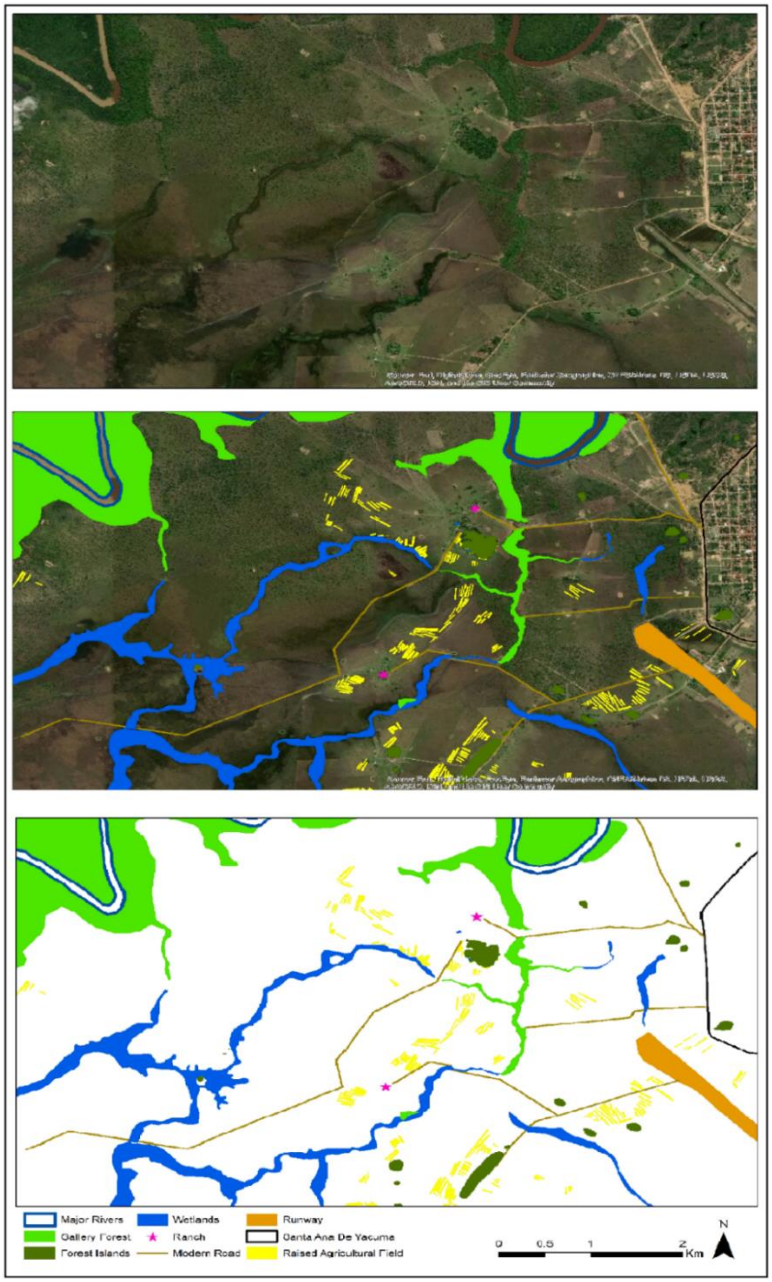
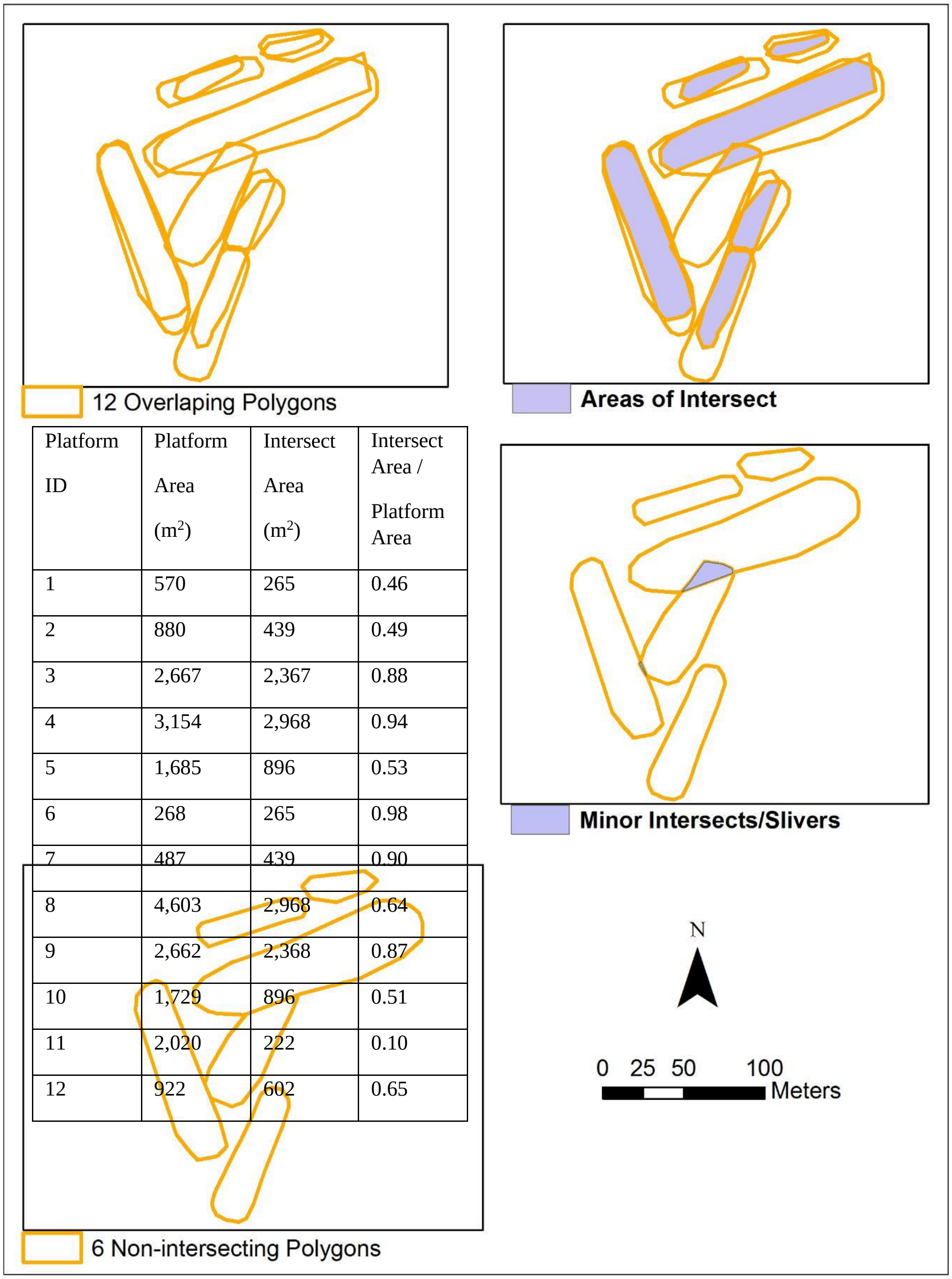


Figure 8: A variety of landscape features are identified in satellite imagery and then digitized in ArcMap & ArcMap online: **(Top)** A satellite image of the landscape southwest of Santa Ana De Yacuma in west Central Mojos. **(Middle)** A variety of landscape features including gallery forests, wetlands, raised agricultural fields, modern roads and runways are identified and marked with points, lines, or polygons in ArcMap. **(Bottom)** The landscape features may be represented and analyzed as points, lines, and polygons separate from the satellite imagery. Spatial analysis of the data includes measuring characteristics such as the size of a landscape feature and its average distance to other features in the landscape.

Figure 9: Satellite imagery of Mojos is regularly improving. **(Top)** Imagery available to Boothby (2012) which shows a range of agricultural fields surrounding San Francisco Forest Island. **(Bottom**) The same location viewed in ArcMap in 2020. Note how in the newer footage the shapes of the platforms appear clearer and the fields appear wider as a result. However, on the right side of the image many raised fields visible in 2012 are barely visible in the 2020 image



Platform ID	Platform Area (m^2)	Intersect Area (m^2)	Intersect Area / Platform Area
1	570	265	0.46
2	880	439	0.49
3	2,667	2,367	0.88
4	3,154	2,968	0.94
5	1,685	896	0.53
6	268	265	0.98
7	487	439	0.90
8	4,603	2,968	0.64
9	2,662	2,368	0.87
10	1,729	896	0.51
11	2,020	222	0.10
12	922	602	0.65

Figure 10: Methods from Lee (2017) were used to sort multiple versions of the same raised field platforms into a single non-intersecting layer with one polygon per raised field platform. **(Top)** Raised field platforms are sorted based on their area of intersect with other platforms. **(Middle)** Platforms with more than 25% of their area falling within another platform are removed from the list. **(Bottom)** The remaining overlaps are merged into the polygon with the longest shared border. The result is a single layer of polygons with one polygon per platform with no overlaps between polygons.

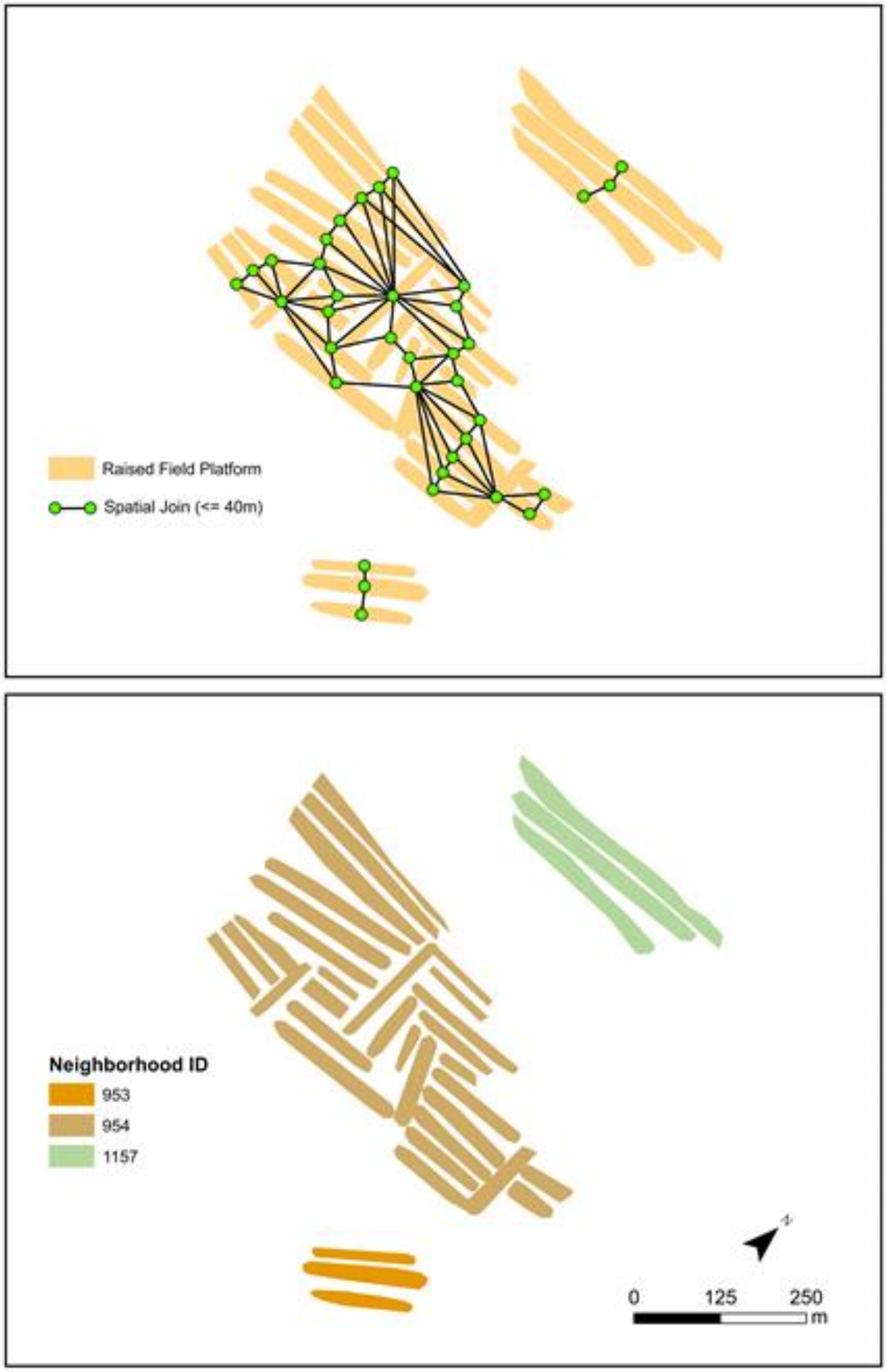


Figure 11: Raised field Neighborhoods are identified based on a 40m proximity rule. **(Top)** In ArcMap, spatial joins are assigned between any platforms that are within 40m of each other. **(Bottom)** All platforms with shared spatial joins are identified as a single Neighborhood and given a unique identification number. Raised field Neighborhoods may be compared with each other based on their characteristics such as their total number of platforms or average size of a platform within a Neighborhood.

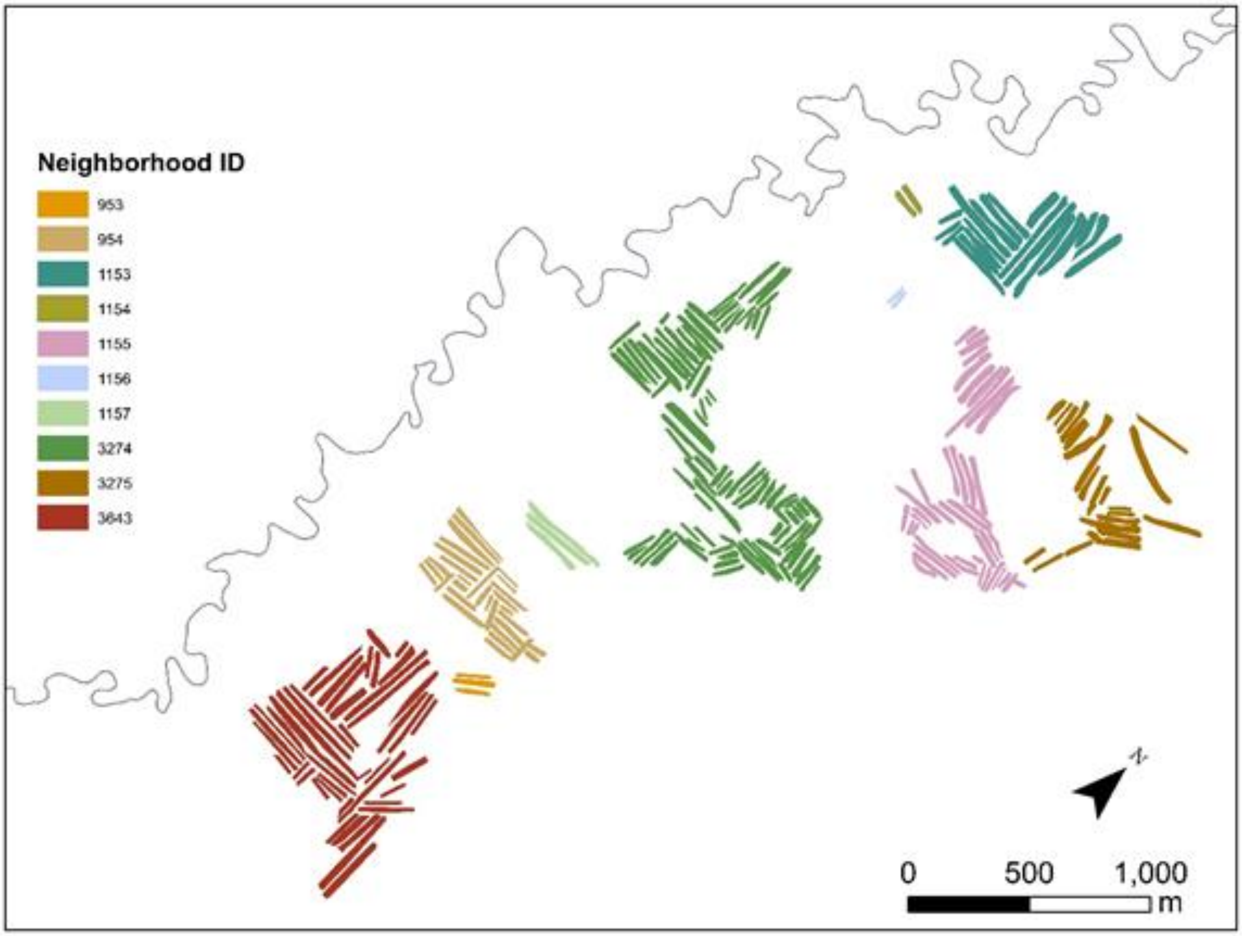


Figure 12: Raised field platforms organized into Neighborhoods based on a 40m proximity rule. Platforms must be within 40 meters of at least one other platform in a Neighborhood to be assigned to that Neighborhood. Platforms at opposite ends of Neighborhoods may be more than 40m apart, however, they will have a continuous spread of platforms between them with no more than 40 meters between adjacent platforms.

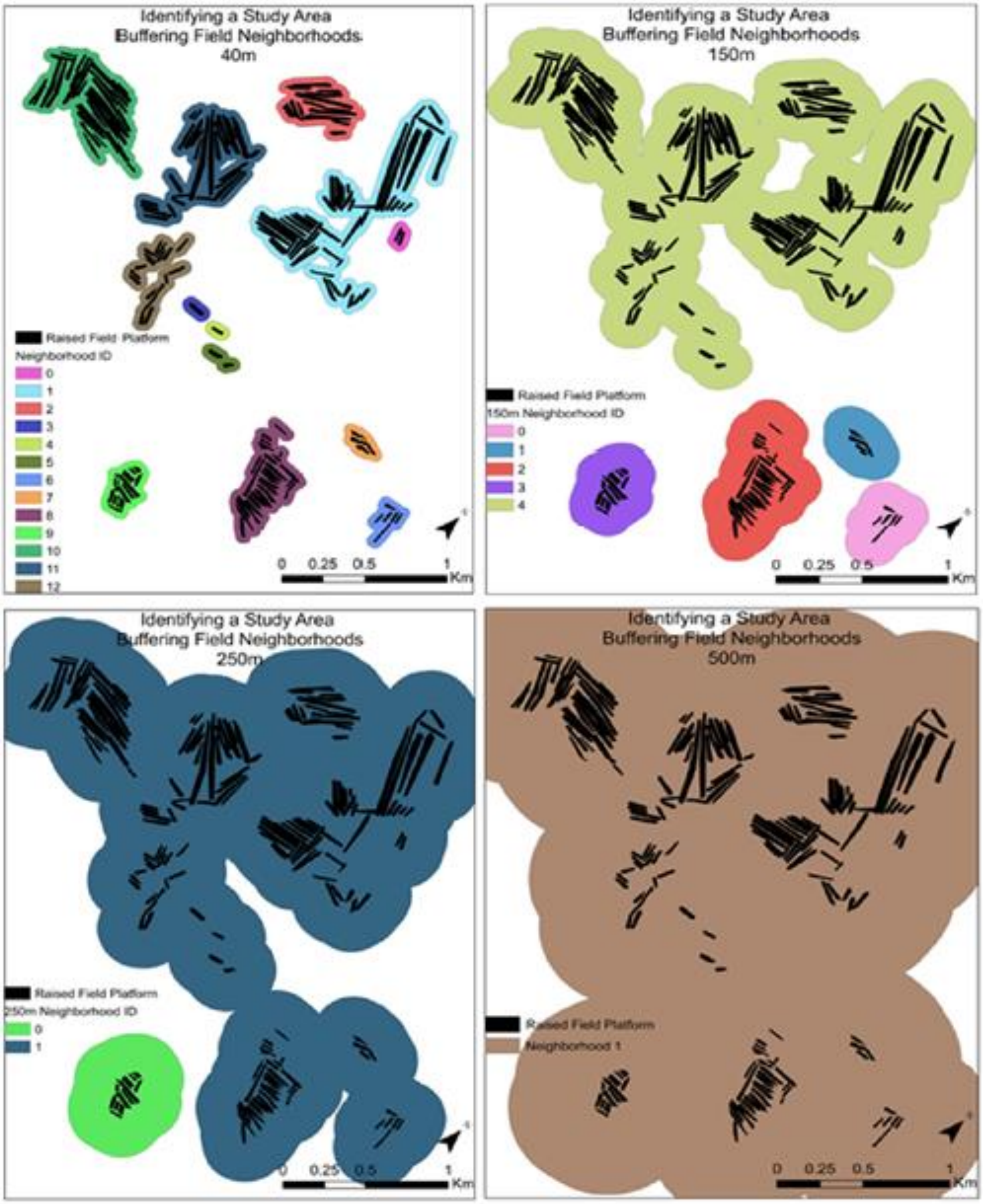


Figure 13: Raised field Neighborhoods are buffered in increasing increments to measure their distribution across the region. The goal was to determine at what distance all raised field Neighborhoods could be combined into a single continuous polygon. See Figure 14 for larger buffer increments.

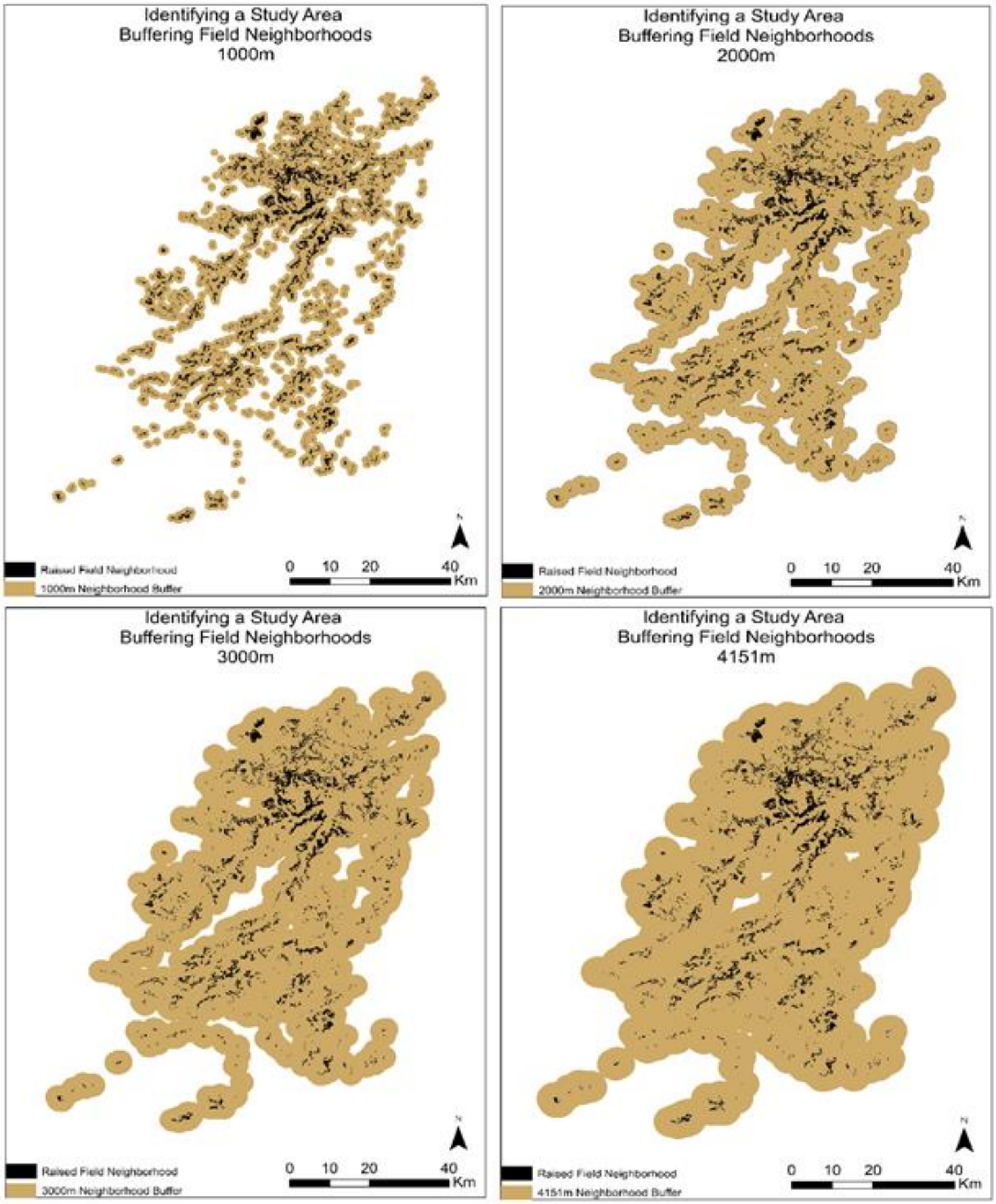


Figure 14: Raised field Neighborhoods are buffered in increasing increments to demonstrate at what distance all Neighborhoods are connected by a single buffer. A buffer of 4,151 meters is required to connect all raised field Neighborhoods into a single area.

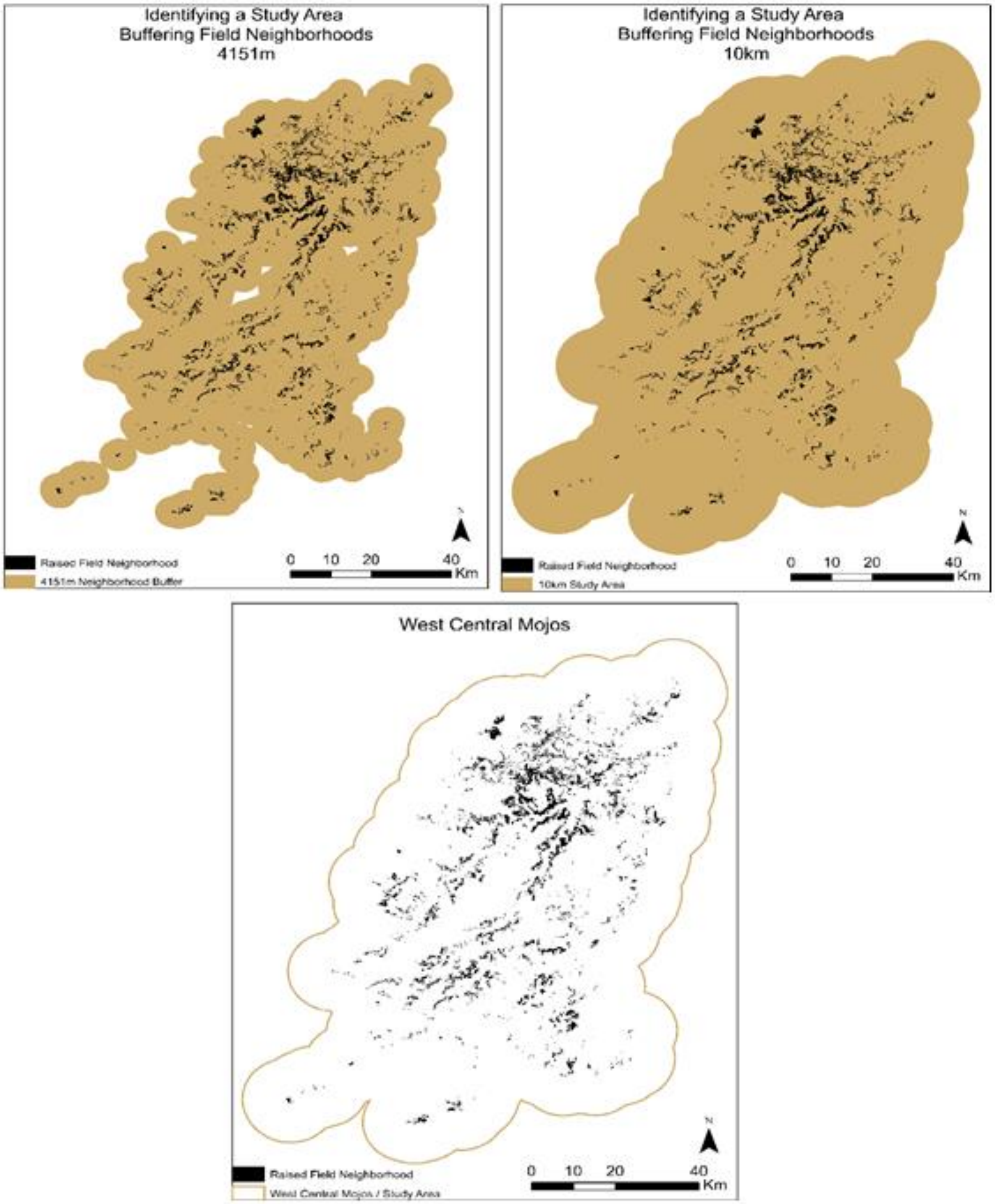


Figure 15: (Top) A buffer of 4,151 meters connects every raised field Neighborhood in Mojos into a single polygon. West central Mojos is defined as any area within 10km of a large raised field Neighborhood. **(Bottom)** The study area for this project is the outer border of west central Mojos defined by a buffer of 10km from the nearest raised agricultural field. This is a continuous region with a clearly defined border.

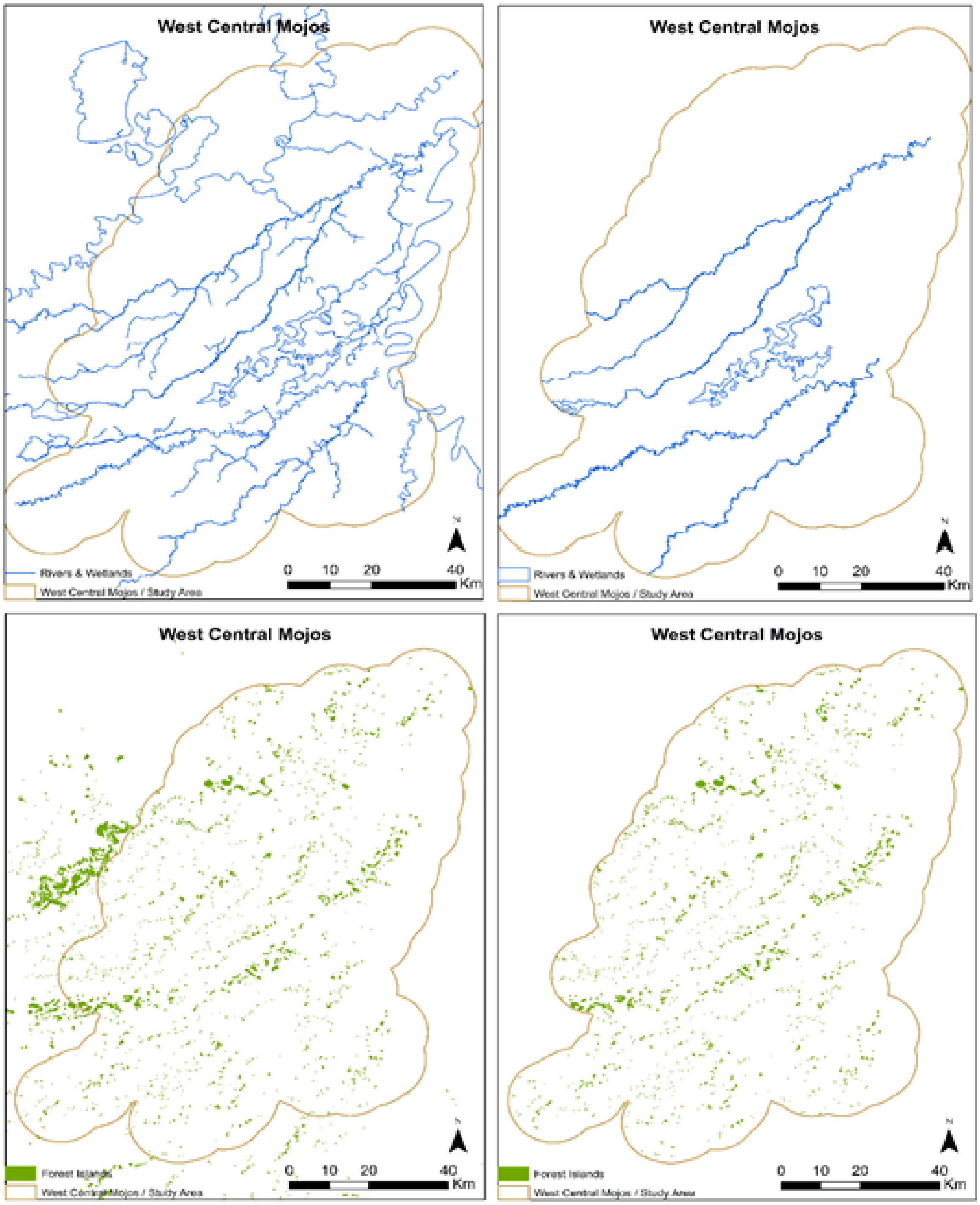


Figure 16: The west central Mojos border is used to select out data for the study. **(Top)** Rivers and wetlands connect west central Mojos with bordering regions in every direction. **(Top Right)** The five major water systems identified by Walker (2018) are selected and reduced to the limits of the study area. **(Bottom Left)** Chains of forest islands extend beyond the study area into other parts of Mojos. **(Bottom Right)** The study area border was used to select out only those forest islands that could be considered part of west central Mojos.

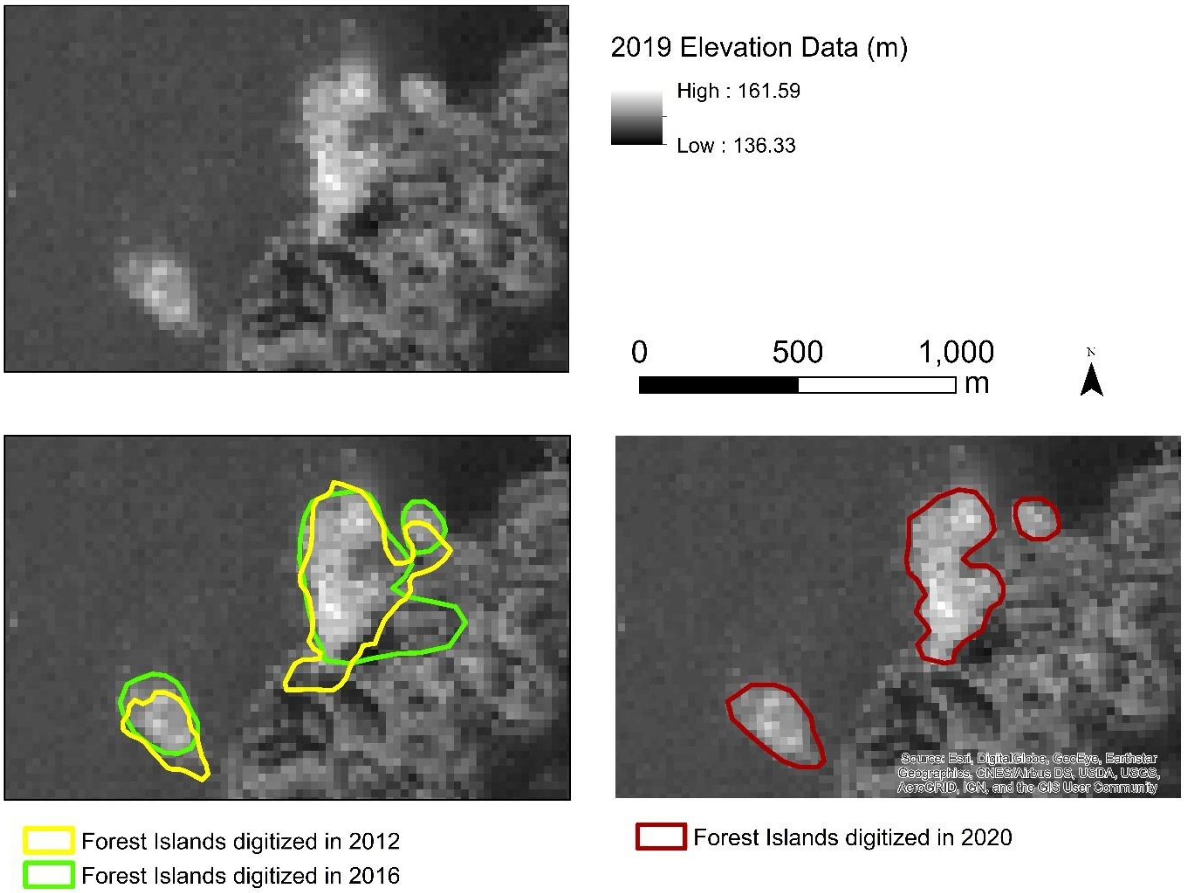


Figure 17: Interpreting the borders of a forest island is not always so straight forward. **(Top)** Digital elevation models can be used to identify areas of high ground in the region. (**Bottom Left)** Digitizing work from 2012 & 2016 is compared to this model indicating that in some instances the separation of the forest island and the surrounding gallery forests is unclear to the digitizer. **(Bottom Right)** The elevation data combined with satellite photos is used to produce more accurate maps of forest islands in 2020.

Figure 18: Finding trees growing atop raised field platforms is not uncommon. However, in the northern portion of the study area there are large patches of forest restricted entirely to the platform areas with no forests spreading into the intervening canals. These forests are clearly different than other forest islands that are generally circular to irregular in shape.

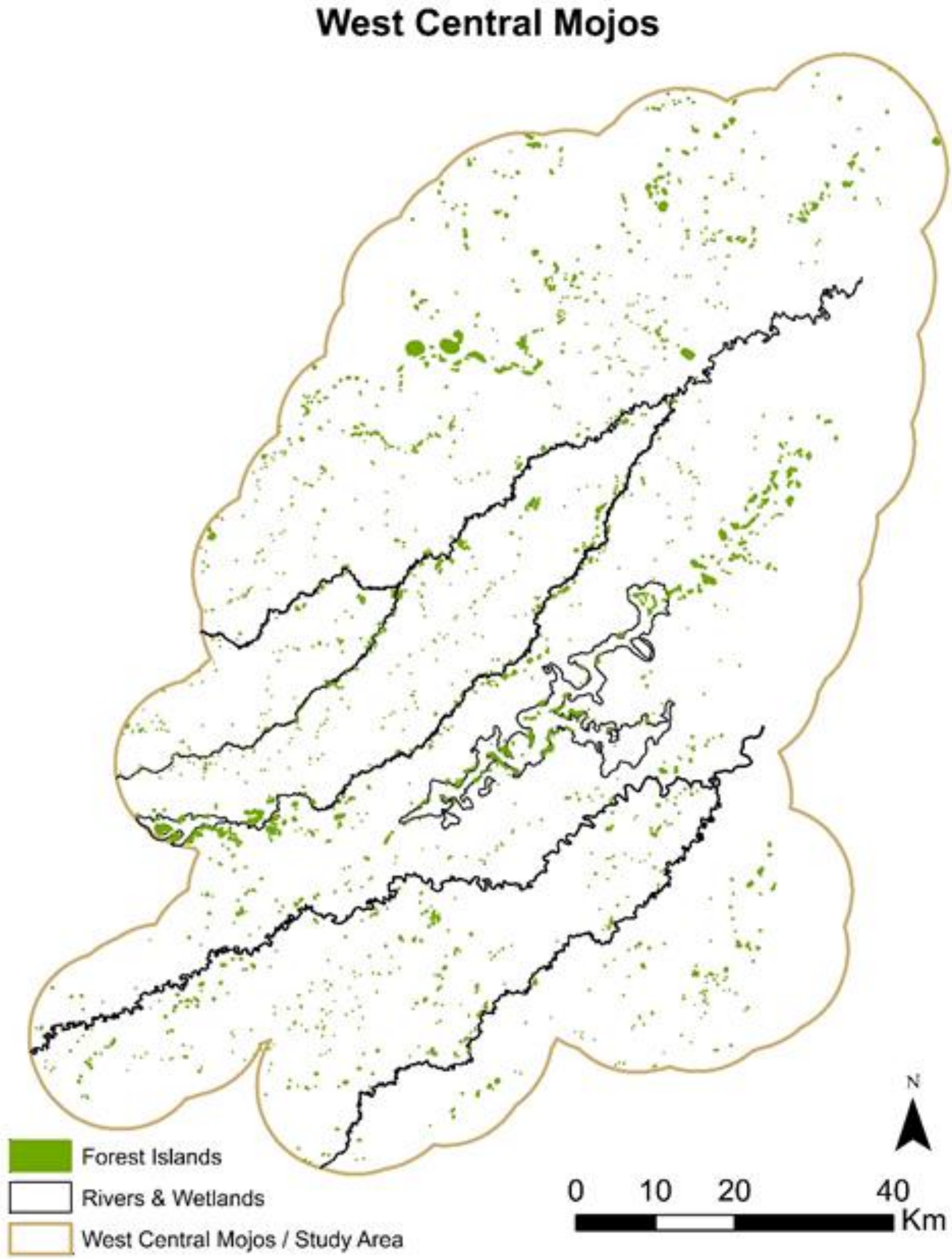


Figure 19: A total of 1,940 polygons representing 8,786.4ha of forest islands were located within the west central Mojos study area. Forest islands are isolated patches of forest that are generally round to irregular in shape and are associated with slightly elevated portions of the landscape that experience less flooding. Forest islands do not include all forested areas in west central Mojos. Flooded forests along the permanent rivers (not shown) were excluded as were patches of forest growing atop rectangular-shaped agricultural fields (see figure 18).

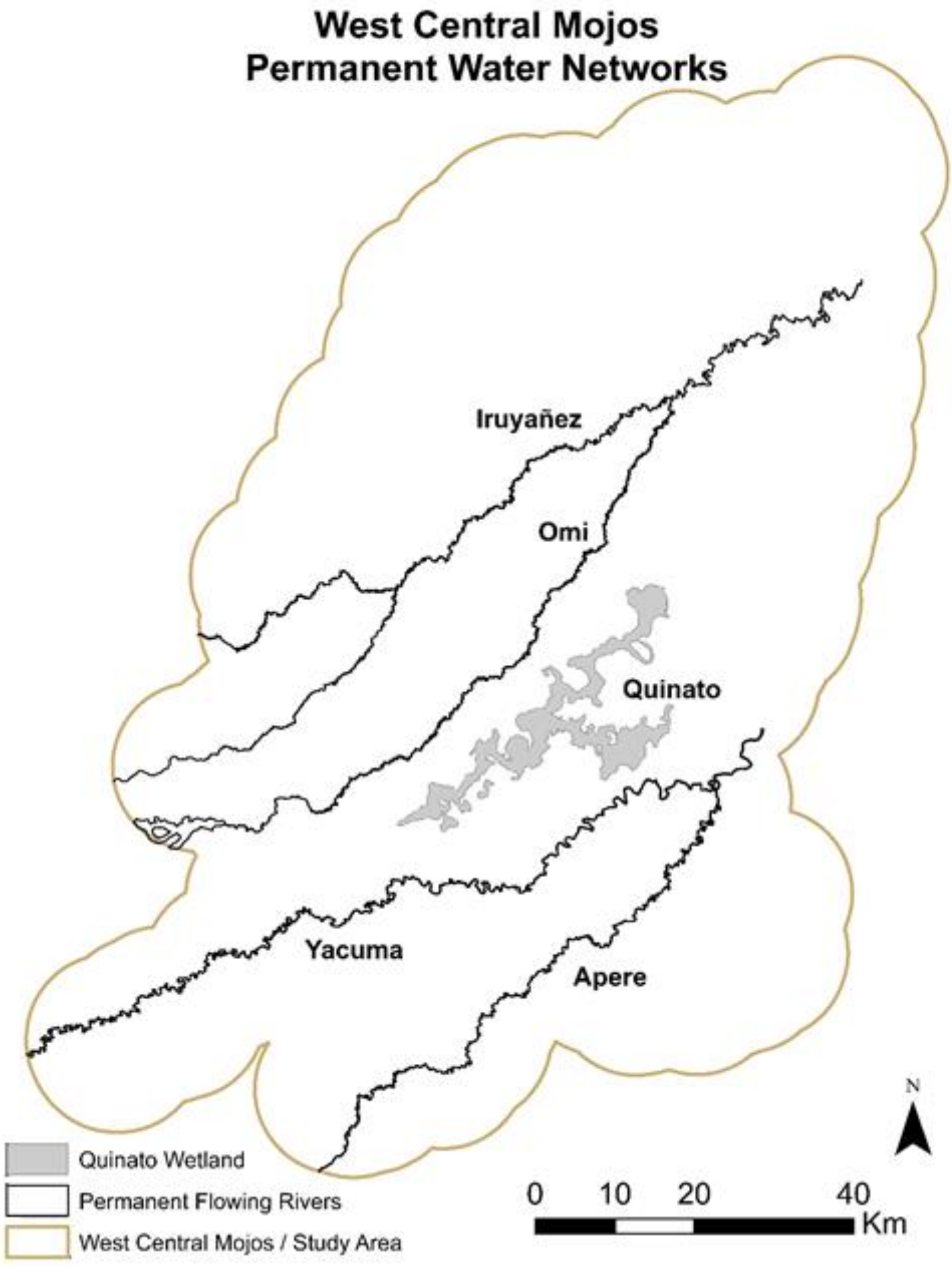


Figure 20: There are four permanent flowing rivers crossing the west central Mojos landscape from southwest to northeast where they connect and join with the Mamore river (not shown). Walker (2018) identifies these four rivers along with the Quinato wetland as the primary water networks associated with the Agropolis Landscape Units. These are not the only wetlands in west central Mojos. A larger network of lakes and seasonal streams not shown here are also scattered across the landscape.

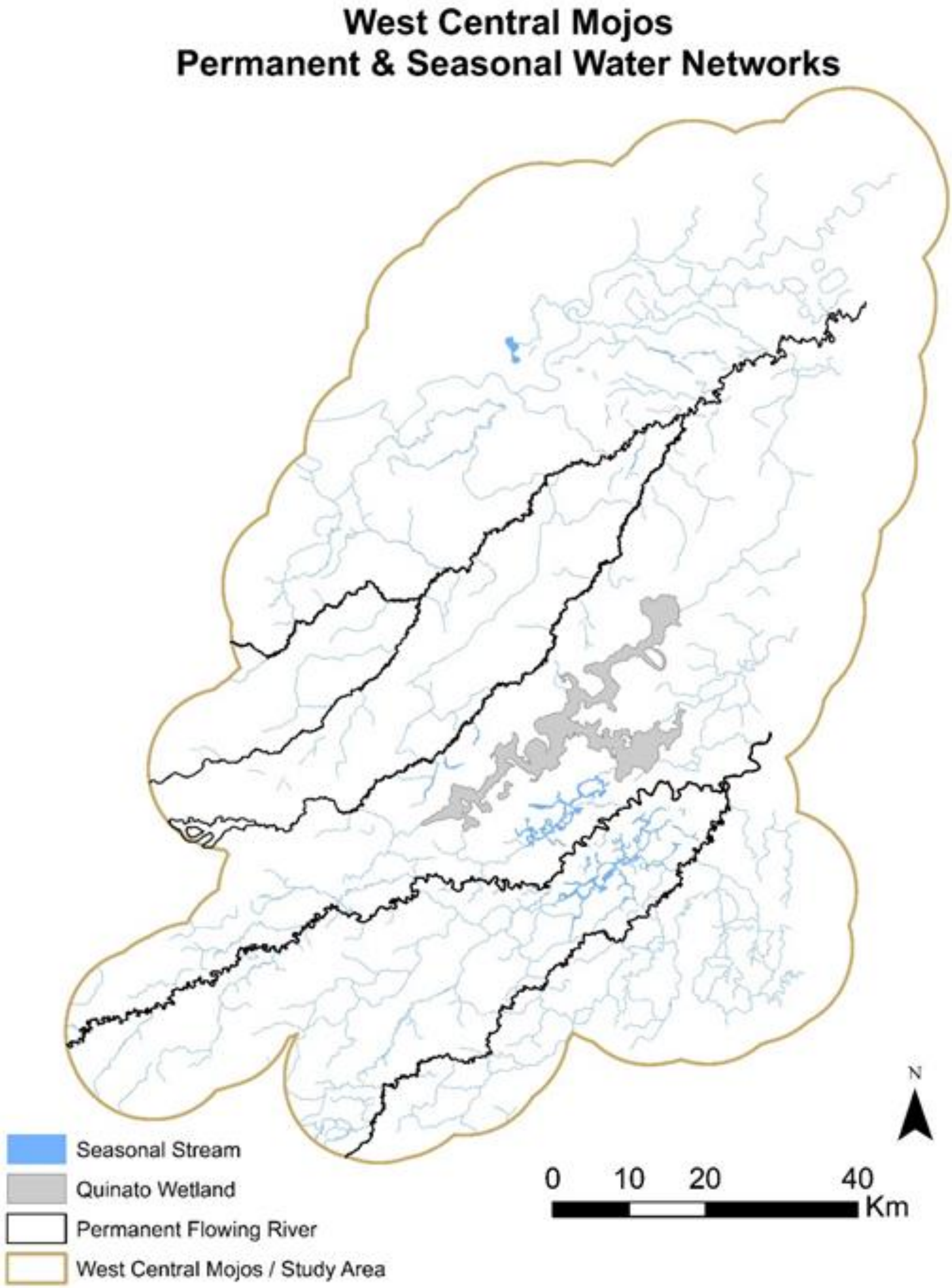


Figure 21: Seasonal streams cross the savannas throughout west central Mojos. This map does not represent the full extent of seasonal streams, lakes, and other wetlands in west central Mojos. Seasonal streams in this project were those with the most clearly identifiable margins as well as those containing connections with the larger permanent river networks.

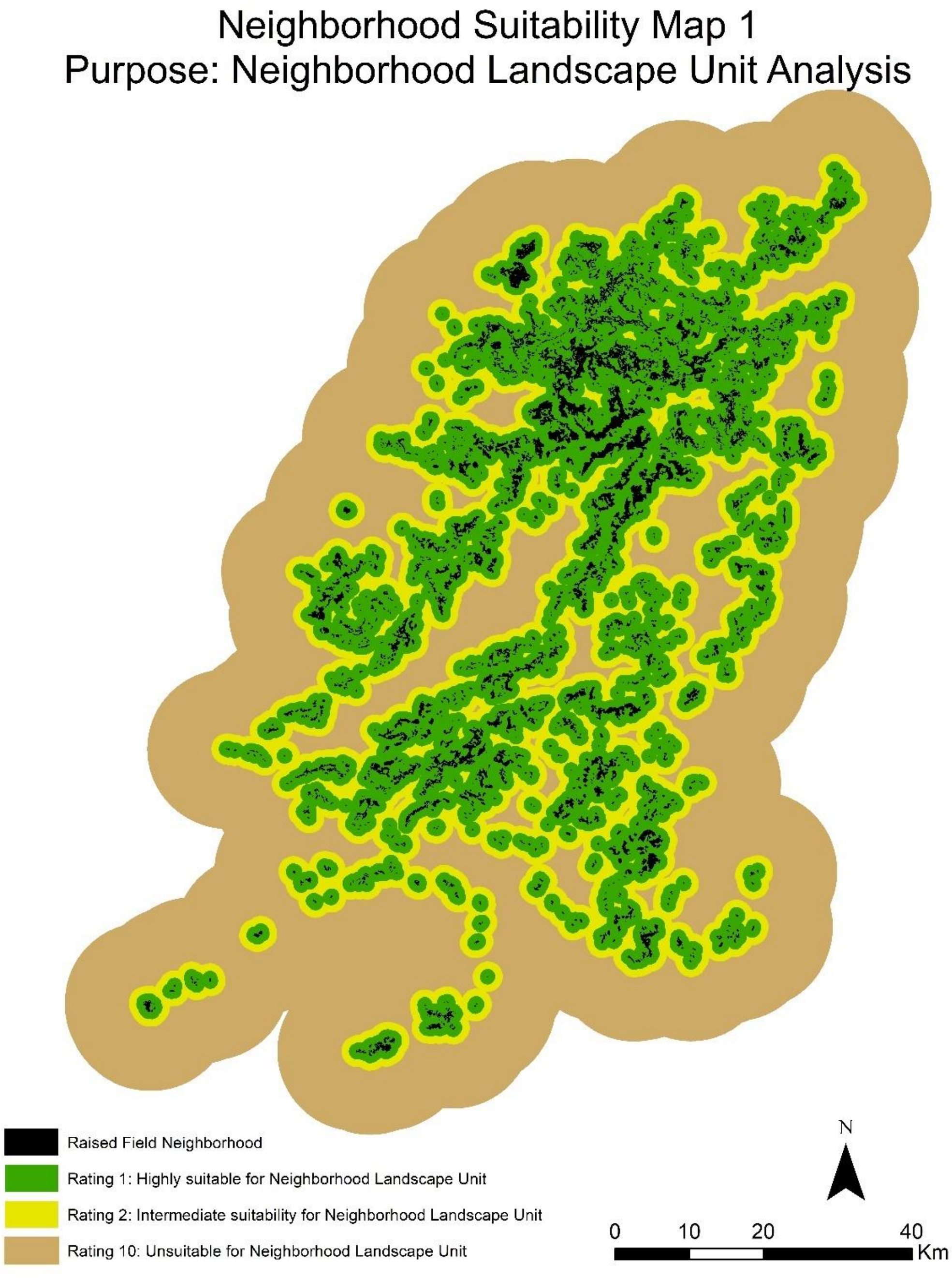


Figure 22: The purpose of Neighborhood Suitability Map 1 is to rate the landscape based on its suitability for selection as part of the Neighborhood Landscape Unit Map. In order to rate the landscape, all raised field Neighborhoods were buffered in 1km increments for 2km. Areas of the landscape beyond 2km from a raised field were considered unsuitable for consideration as part of the Neighborhood Landscape Units.

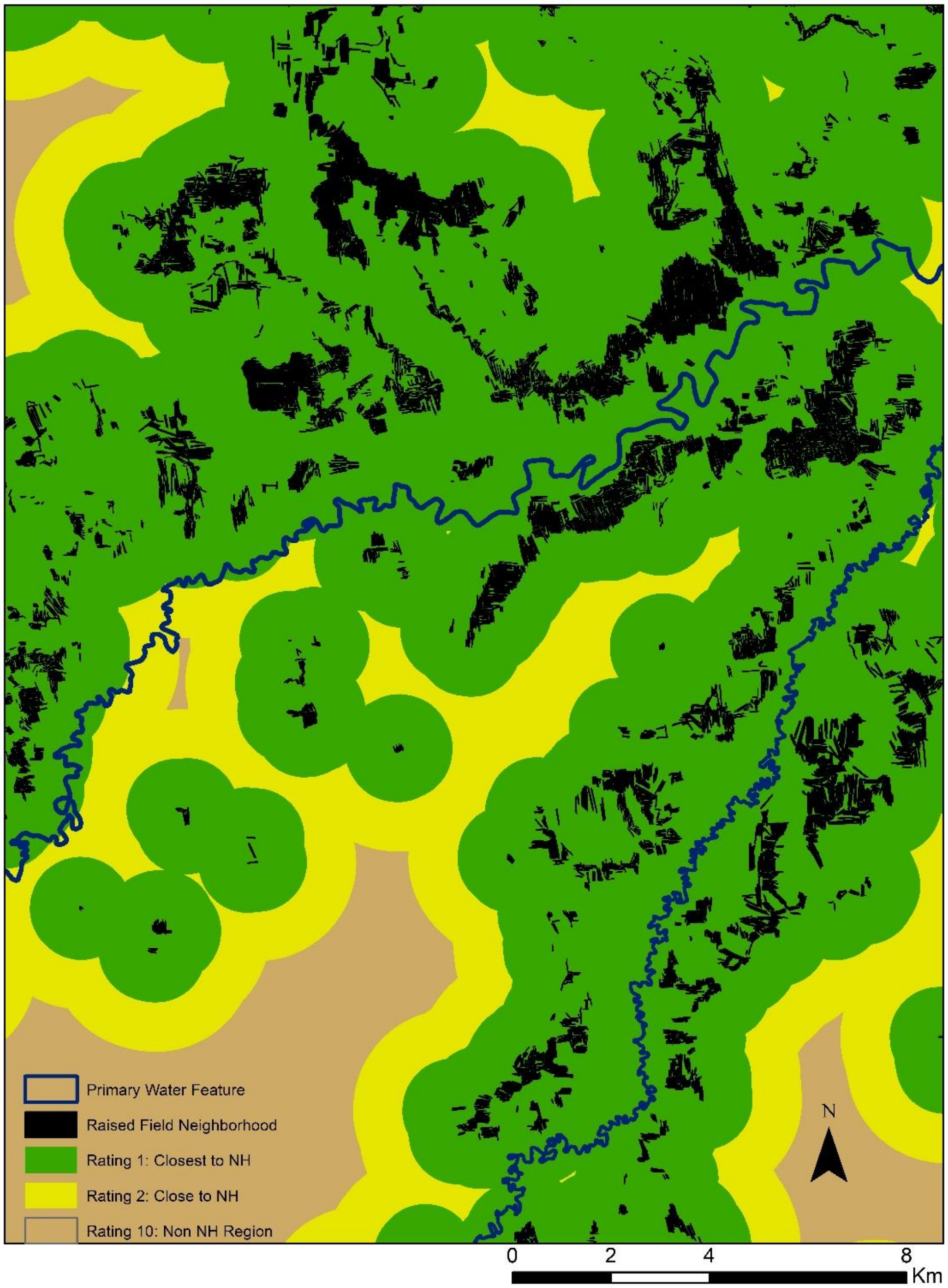


Figure 23: The purpose of Neighborhood Suitability Map 1 is to rate the landscape based on its suitability for selection as part of the Neighborhood Landscape Unit Map. In order to rate the landscape, all raised field Neighborhoods were buffered in 1km increments for 2km. Areas of the landscape beyond 2km from a raised field were considered unsuitable for consideration as part of the Neighborhood Landscape Units

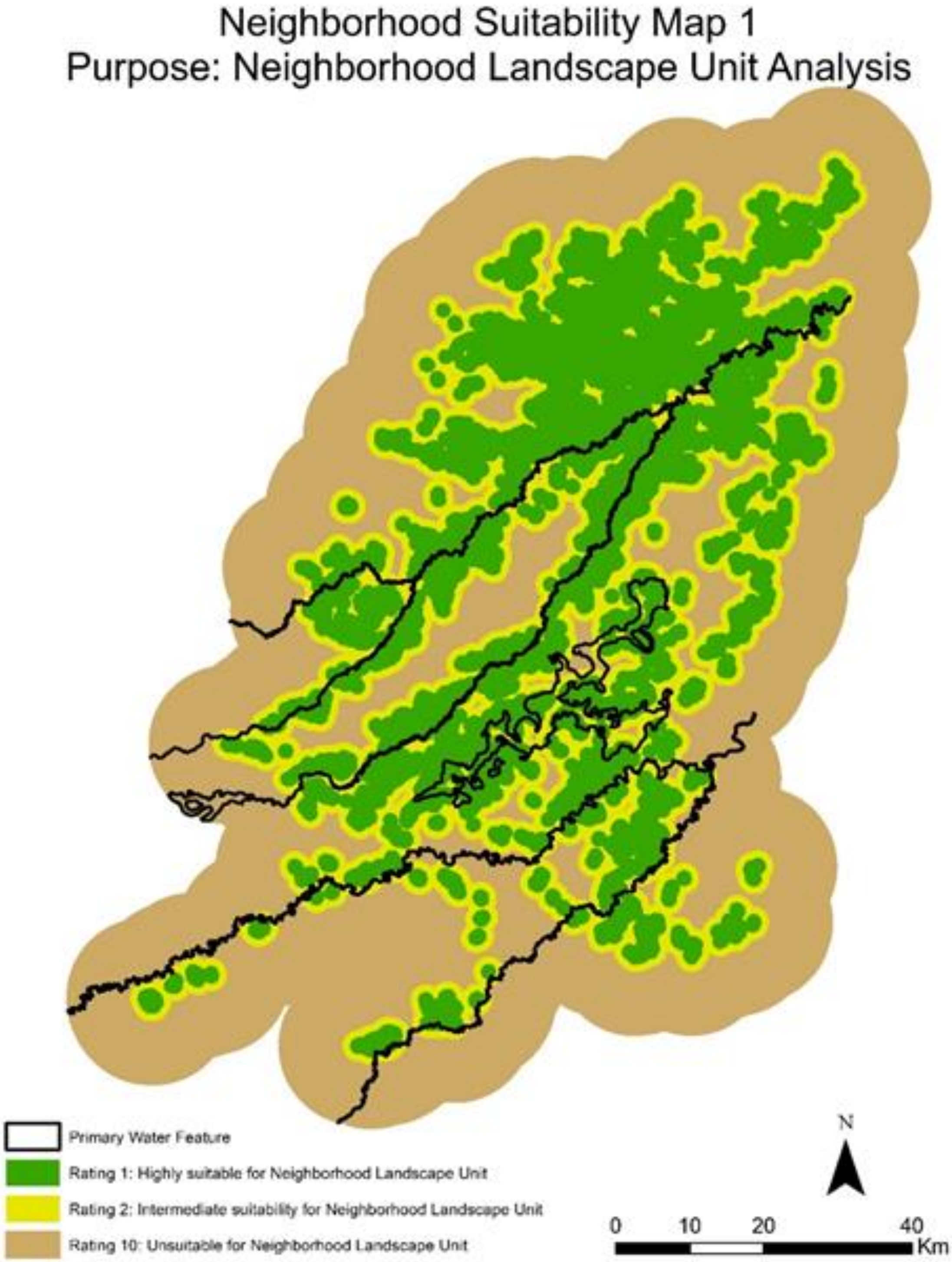


Figure 24: The purpose of Neighborhood Suitability Map 1 is to rate the landscape based on its suitability for selection as part of the Neighborhood Landscape Unit Map. In order to rate the landscape, all raised field Neighborhoods were buffered in 1km increments for 2km. Areas of the landscape beyond 2km from a raised field were considered unsuitable for consideration as part of the Neighborhood Landscape Units.

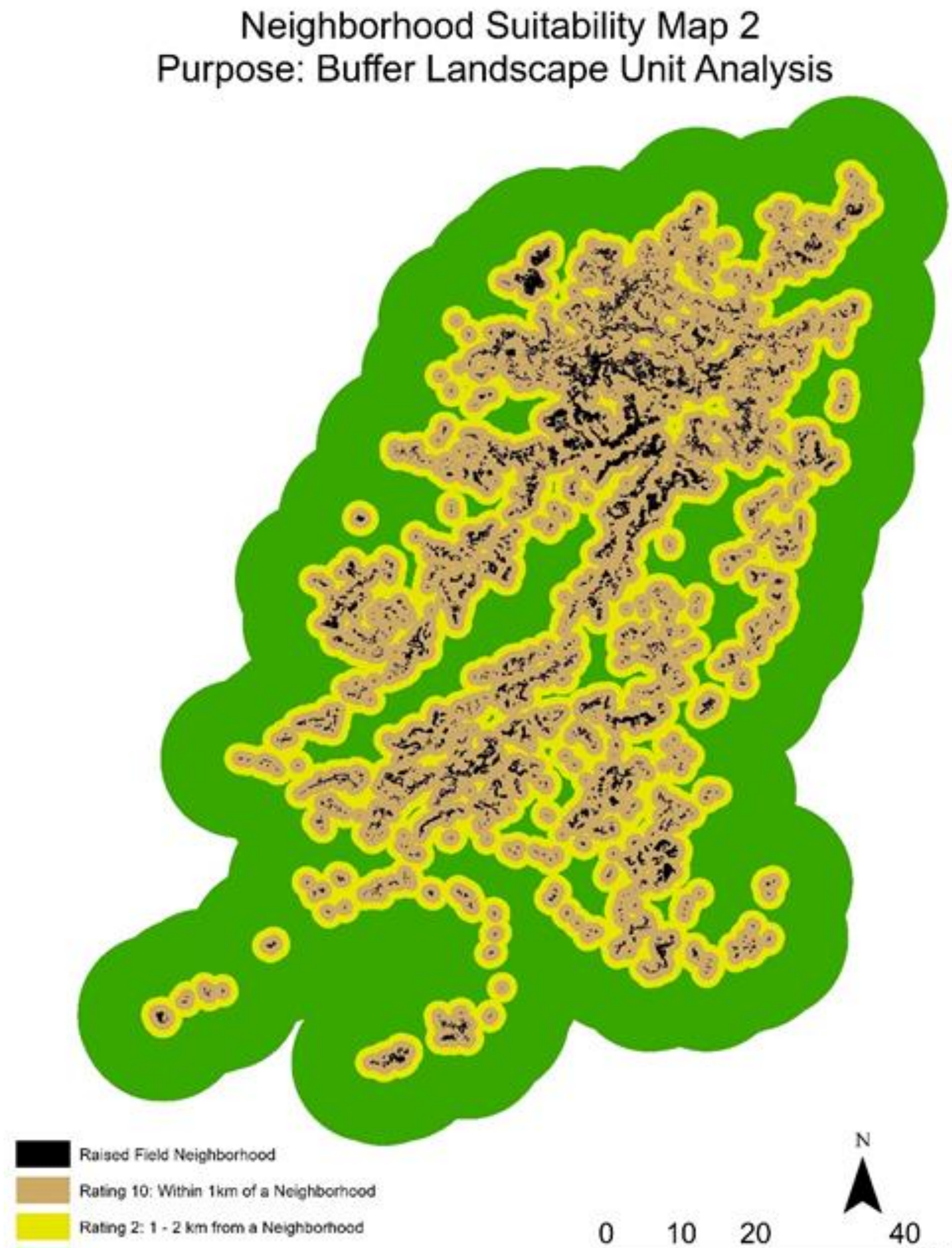


Figure 25: The purpose of Neighborhood Suitability Map 2 is to rate the landscape based on suitability for selection as part of the Buffer Landscape Unit Map. All areas within 1km of a raised field platform are considered unsuitable for consideration as a Buffer Landscape Unit and are assigned a value of 10. Highly suitable areas are those areas more than 2km from a raised field Neighborhood. This map was combined with Forest Island Suitability Map 1 in order to create the Buffer Landscape Suitability Map.

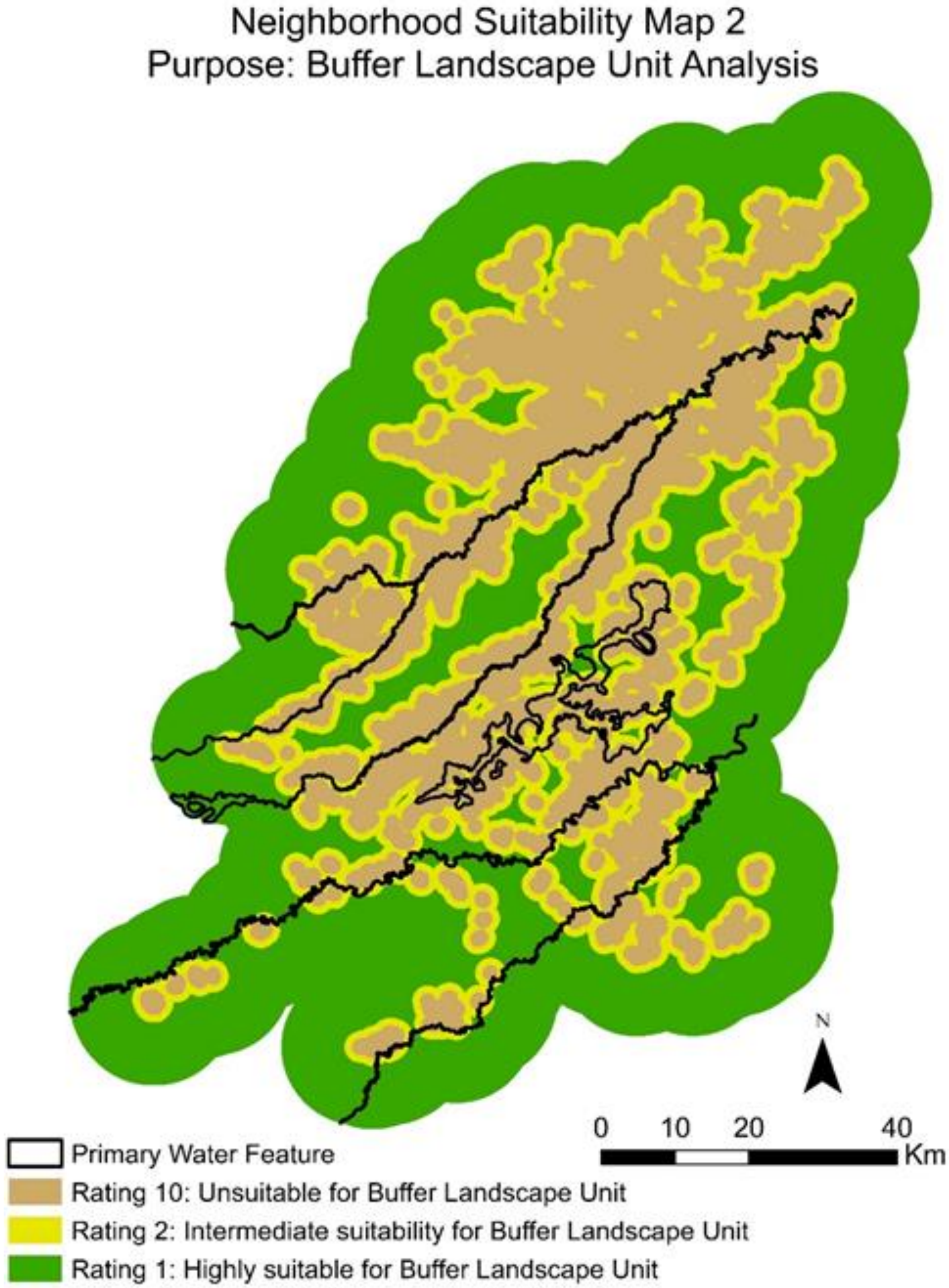


Figure 26: The purpose of Neighborhood Suitability Map 2 is to rate the landscape based on suitability for selection as part of the Buffer Landscape Unit Map. All areas within 1km of a raised field platform are considered unsuitable for consideration as a Buffer Landscape Unit and are assigned a value of 10. Highly suitable areas are those areas more than 2km from a raised field Neighborhood. This map was combined with Forest Island Suitability Map 1 in order to create the Buffer Landscape Suitability Map.

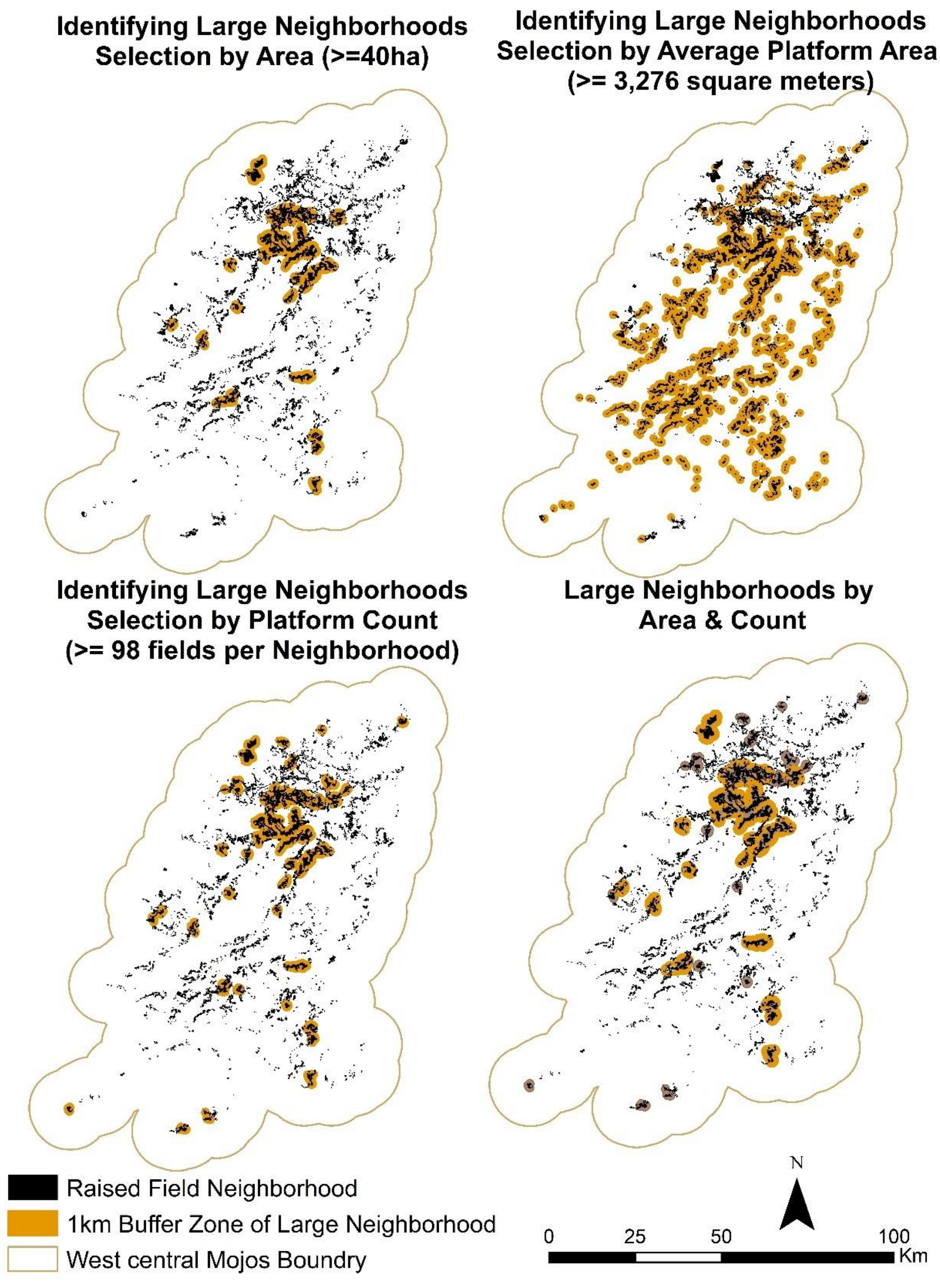


Figure 27: Identifying large and small raised field Neighborhoods requires selecting the criteria for large and small. This figure demonstrates how the selection of large fields changes in distribution when the criteria changes from Neighborhood surface area to platform surface area and to platform count. Ultimately platform count was chosen as a method for choosing between large and small Neighborhoods.

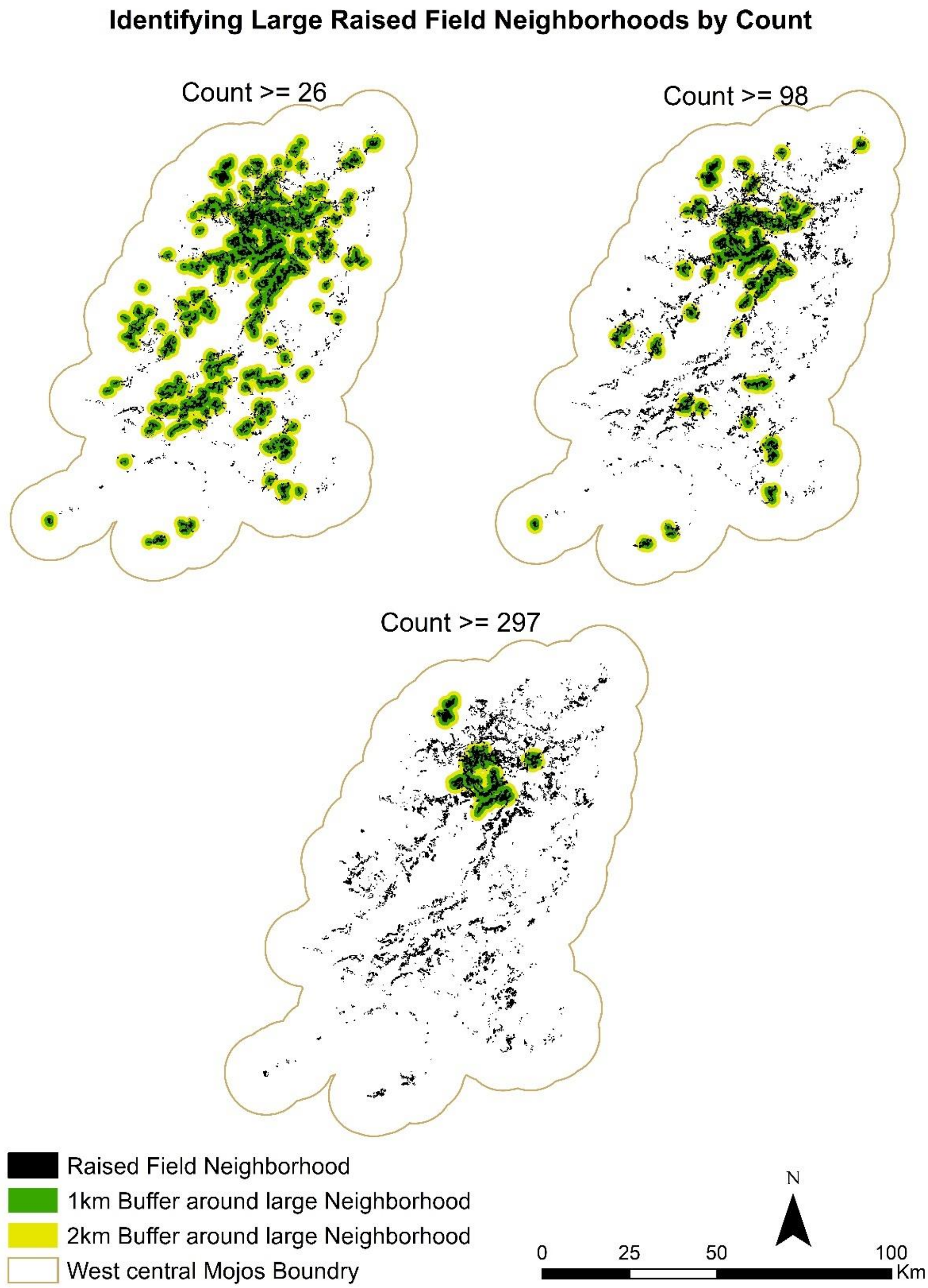


Figure 28: Identifying large and small raised field Neighborhoods requires selecting the criteria for large and small. This figure demonstrates how the distribution of large Neighborhoods changes when the cutoff value for large fields is changed. The platform counts for all raised field Neighborhoods were placed in a list and divided into 5 statistical breaks (Natural Jenks). Each image above has the cutoff size of a raised field set to a different break in the data. Ultimately all fields in the third break and above (>= 98) were used to identify large field Neighborhoods in the project.

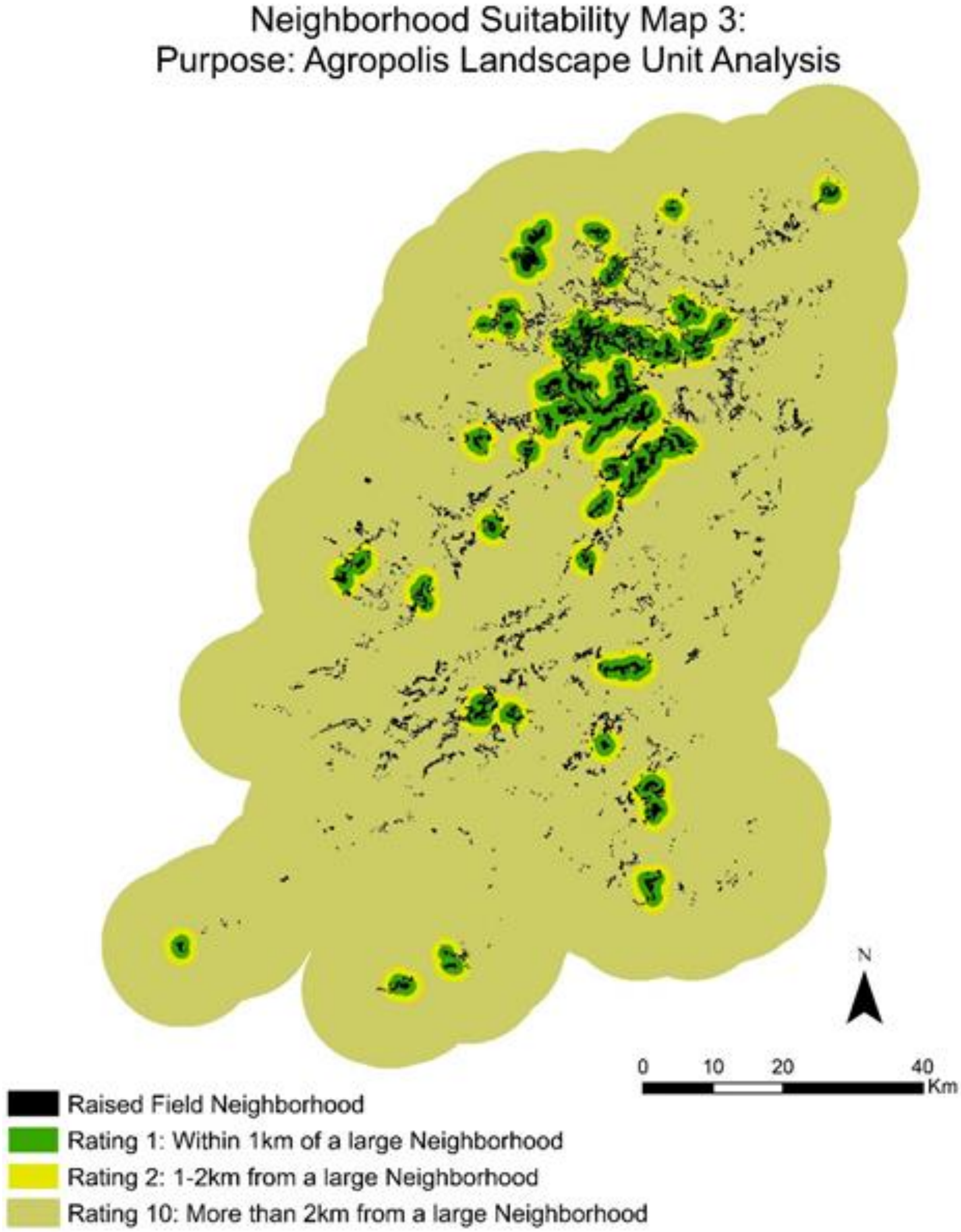


Figure 29: The purpose of Neighborhood Suitability Map 3 is to rate the landscape based on proximity to large raised field Neighborhoods. This map was combined with Forest Island Suitability Map 2 and the Permanent Water Network Suitability Map to create the Combined Agropolis Suitability Map.

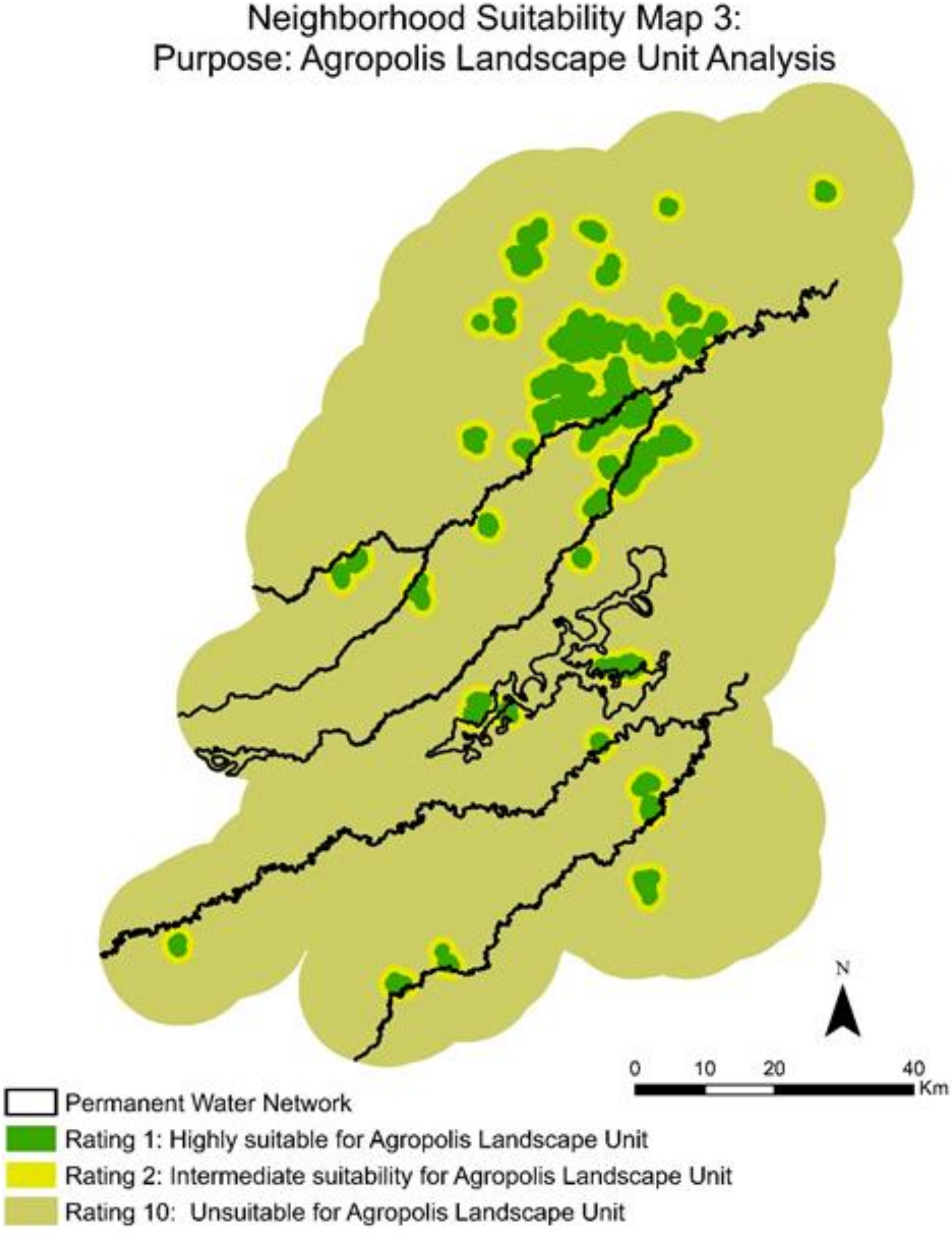


Figure 30: The purpose of Neighborhood Suitability Map 3 is to rate the landscape based on proximity to large raised field Neighborhoods. This map was combined with Forest Island Suitability Map 2 and the Permanent Water Network Suitability Map to create the Combined Agropolis Suitability Map.

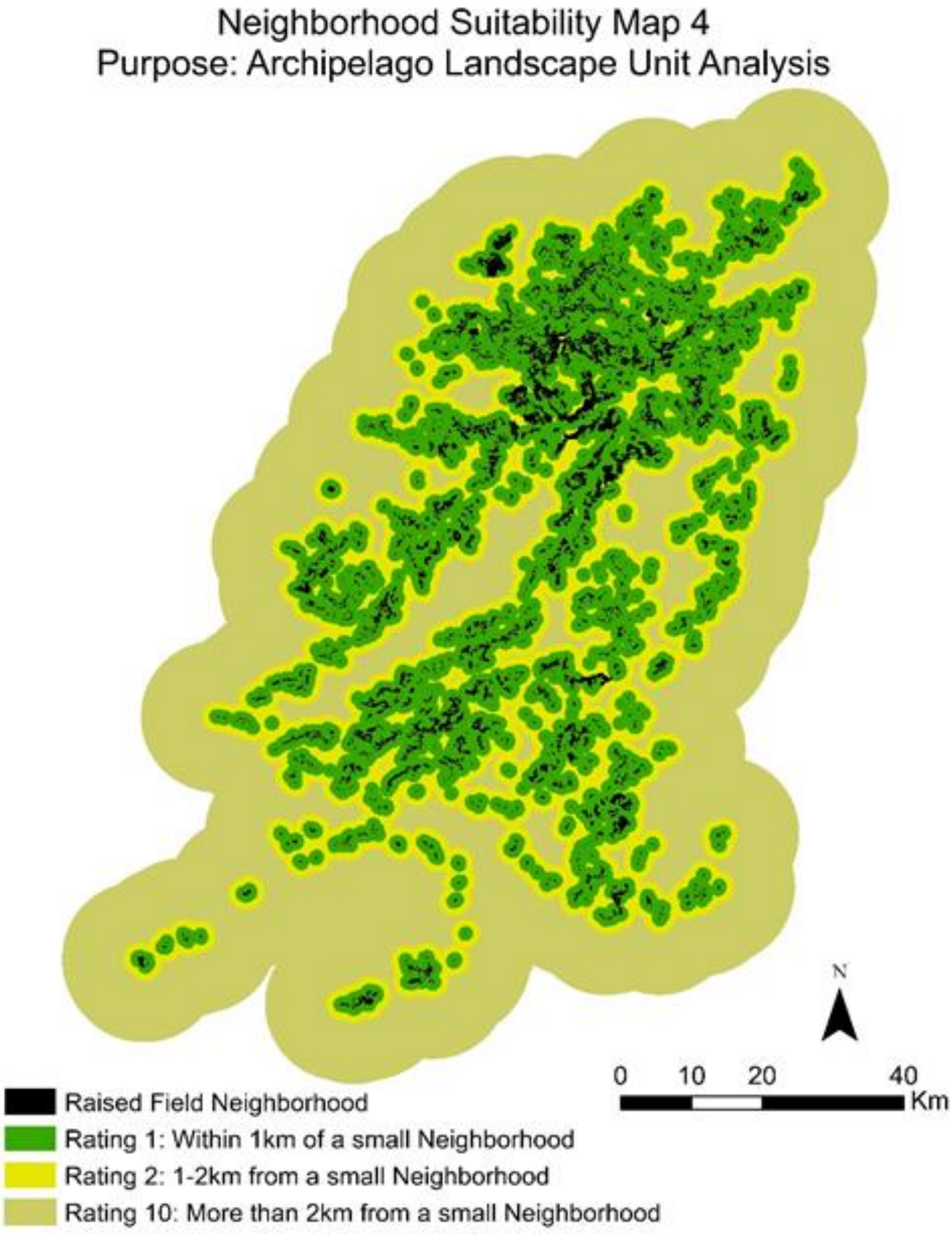


Figure 31: The purpose of Neighborhood Suitability Map 4 was to rate the landscape based on proximity to small raised field Neighborhoods. This map was combined with Forest Island Suitability Map 3 and the Seasonal Water Network Suitability Map to create the Combined Archipelago Suitability Map.

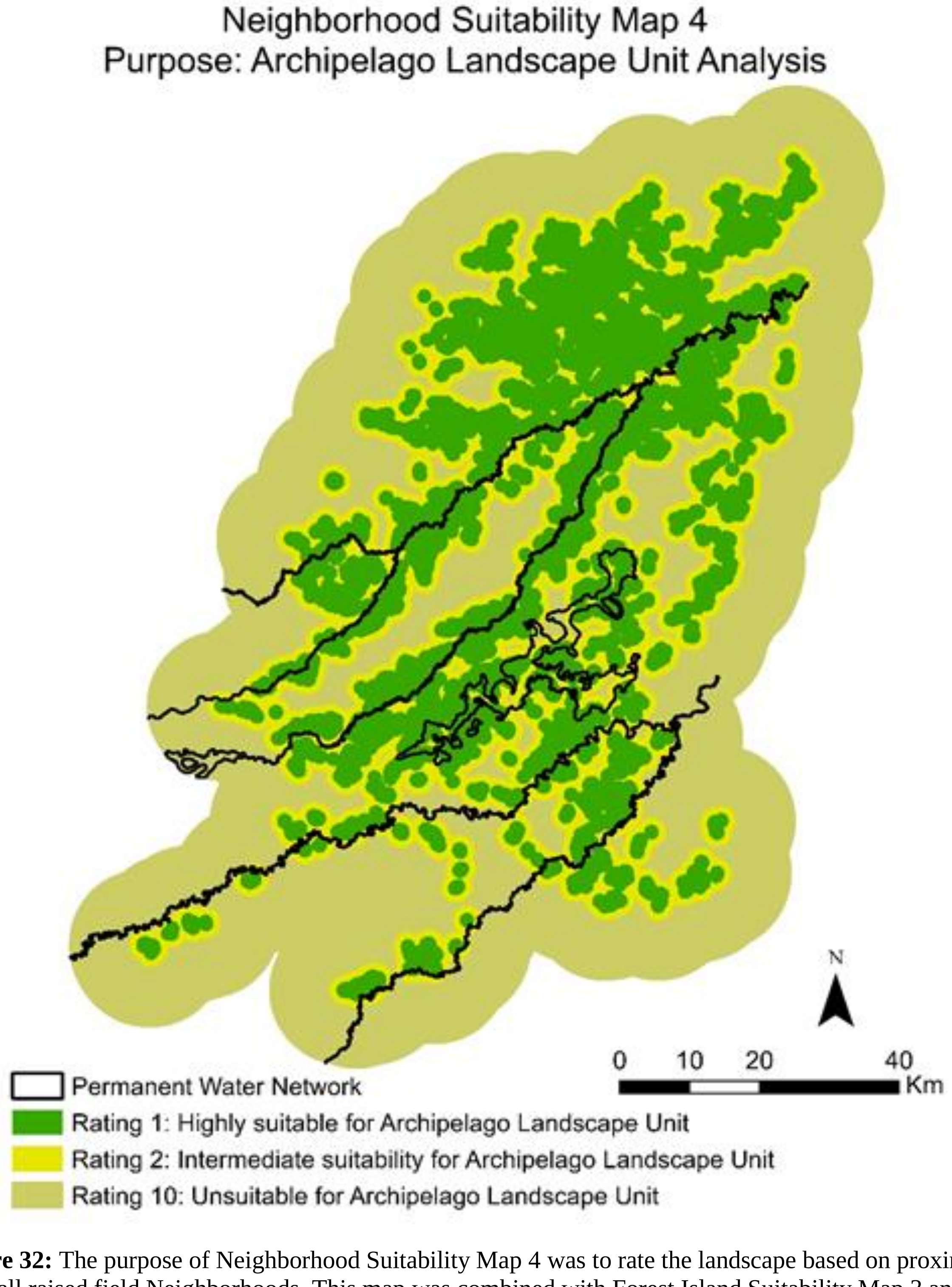


Figure 32: The purpose of Neighborhood Suitability Map 4 was to rate the landscape based on proximity to small raised field Neighborhoods. This map was combined with Forest Island Suitability Map 3 and the Seasonal Water Network Suitability Map to create the Combined Archipelago Suitability Map.

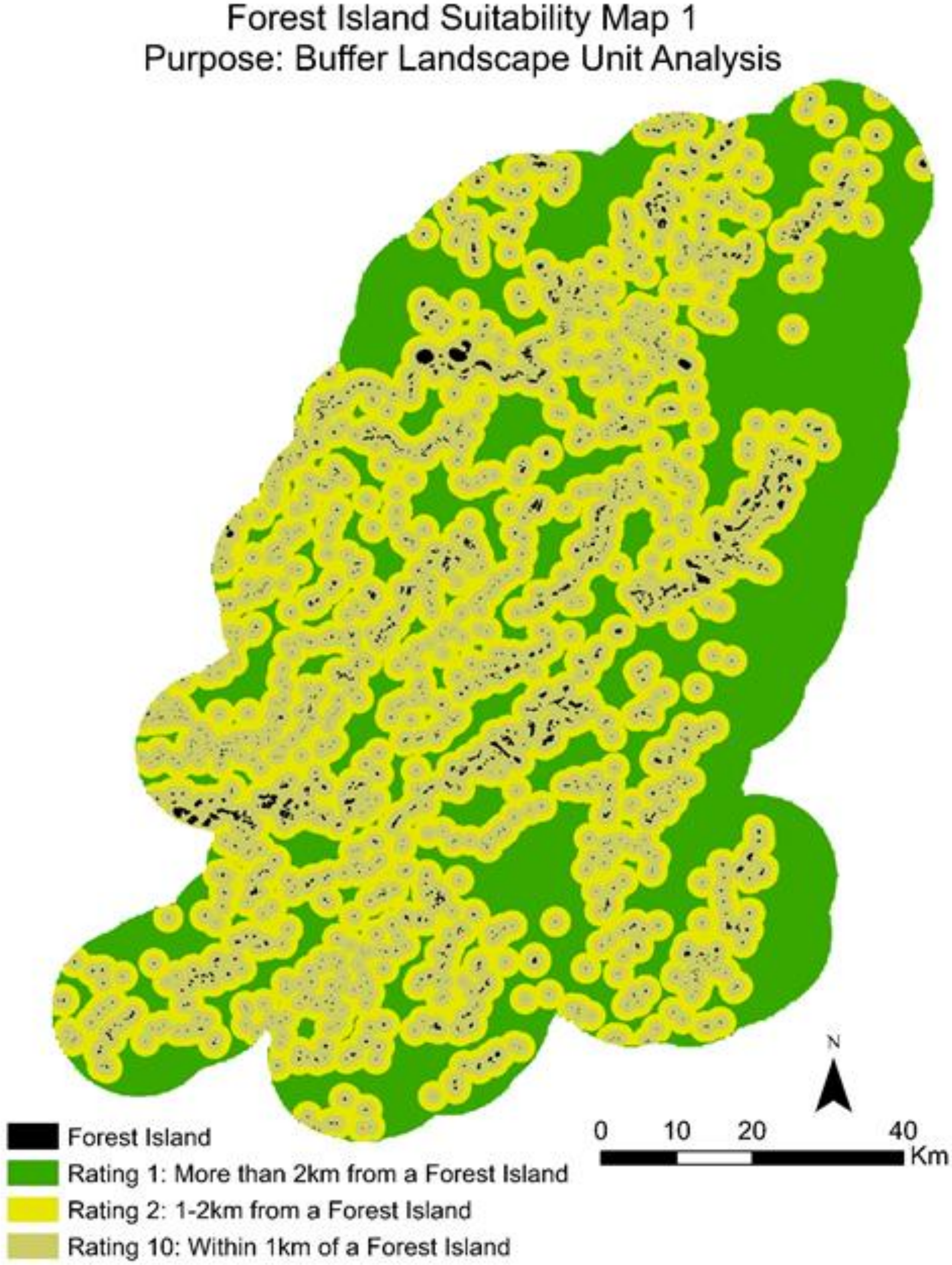


Figure 33: The purpose of Forest Island Suitability Map 1 was to rate the landscape based on proximity to Forest Islands of any size. This map was combined with Neighborhood Suitability Map 2 to create the Combined Buffer Suitability Map.

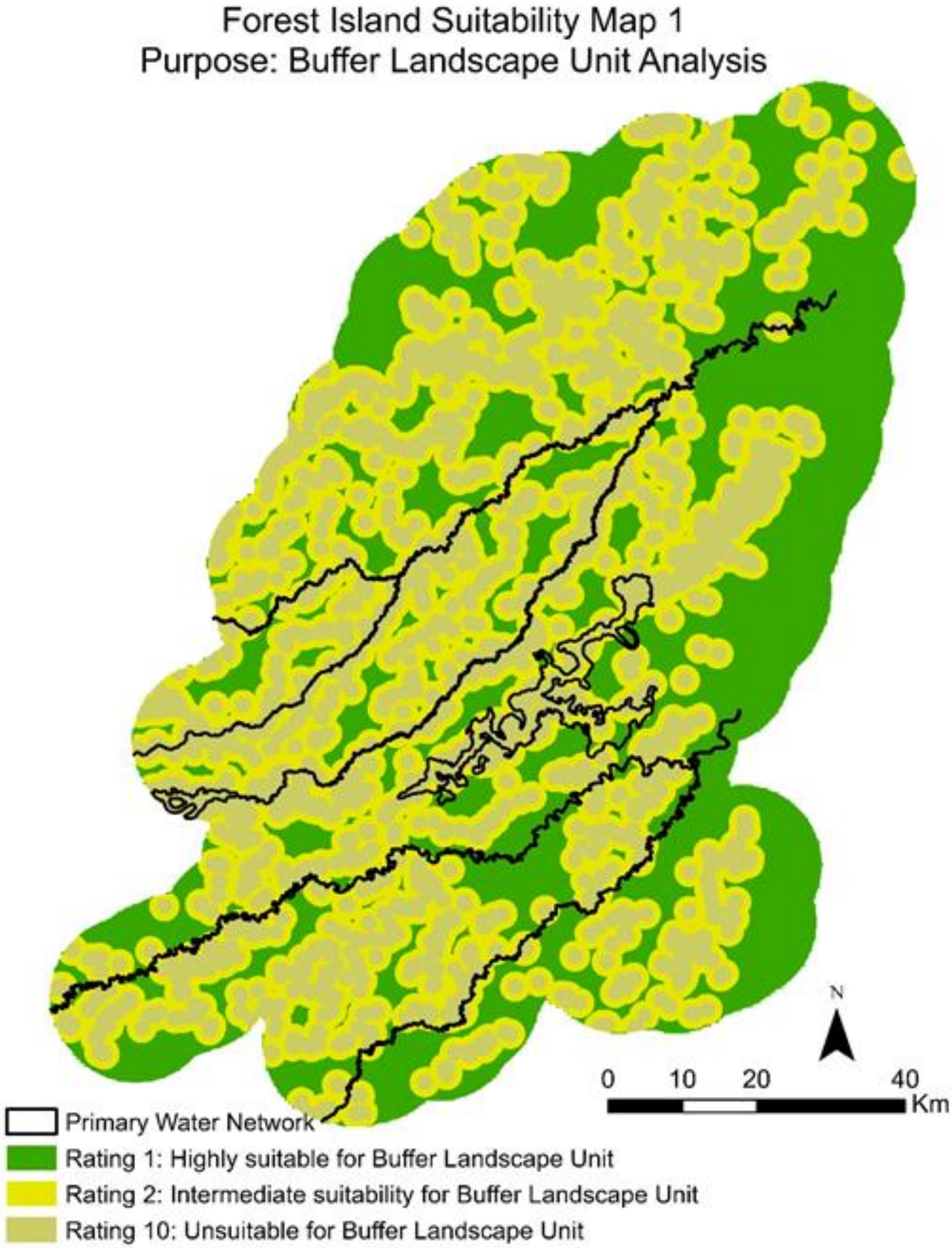


Figure 34: The purpose of Forest Island Suitability Map 1 is to rate the landscape based on proximity to Forest Islands of any size. This map was combined with Neighborhood Suitability Map 2 to create the Combined Buffer Suitability Map.

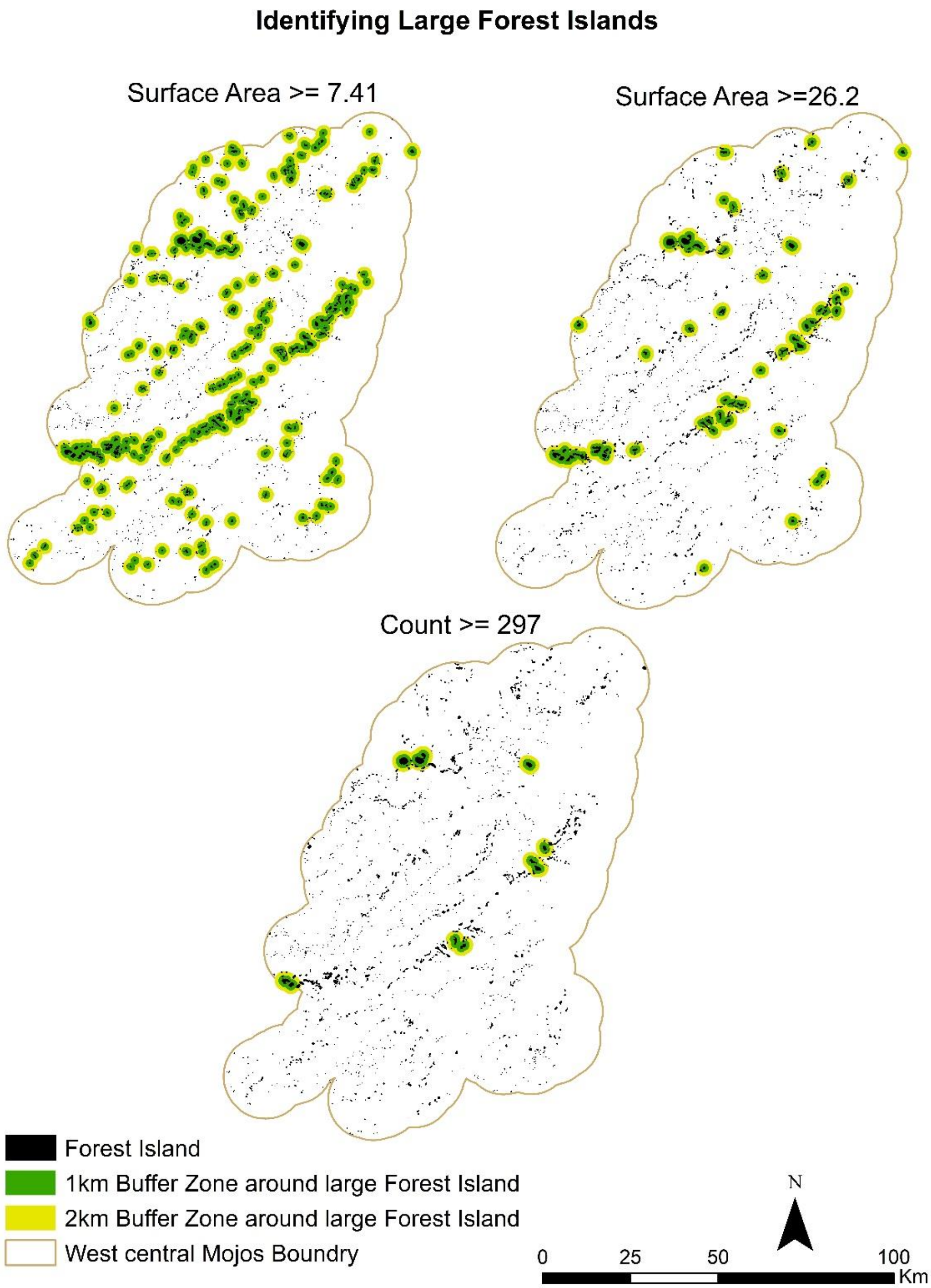


Figure 35: Identifying large Forest Islands requires selecting the criteria for large. This figure demonstrates how the distribution of large forest islands changes when the cutoff value for the large category is changed. The surface areas for all forest islands were calculated and placed in a list and divided into 5 statistical breaks (Natural Jenks). Each image above has the cutoff size for a large forest island set to a different break in the data. Ultimately all forest islands greater than 26.2ha were selected as large forest islands for this project.

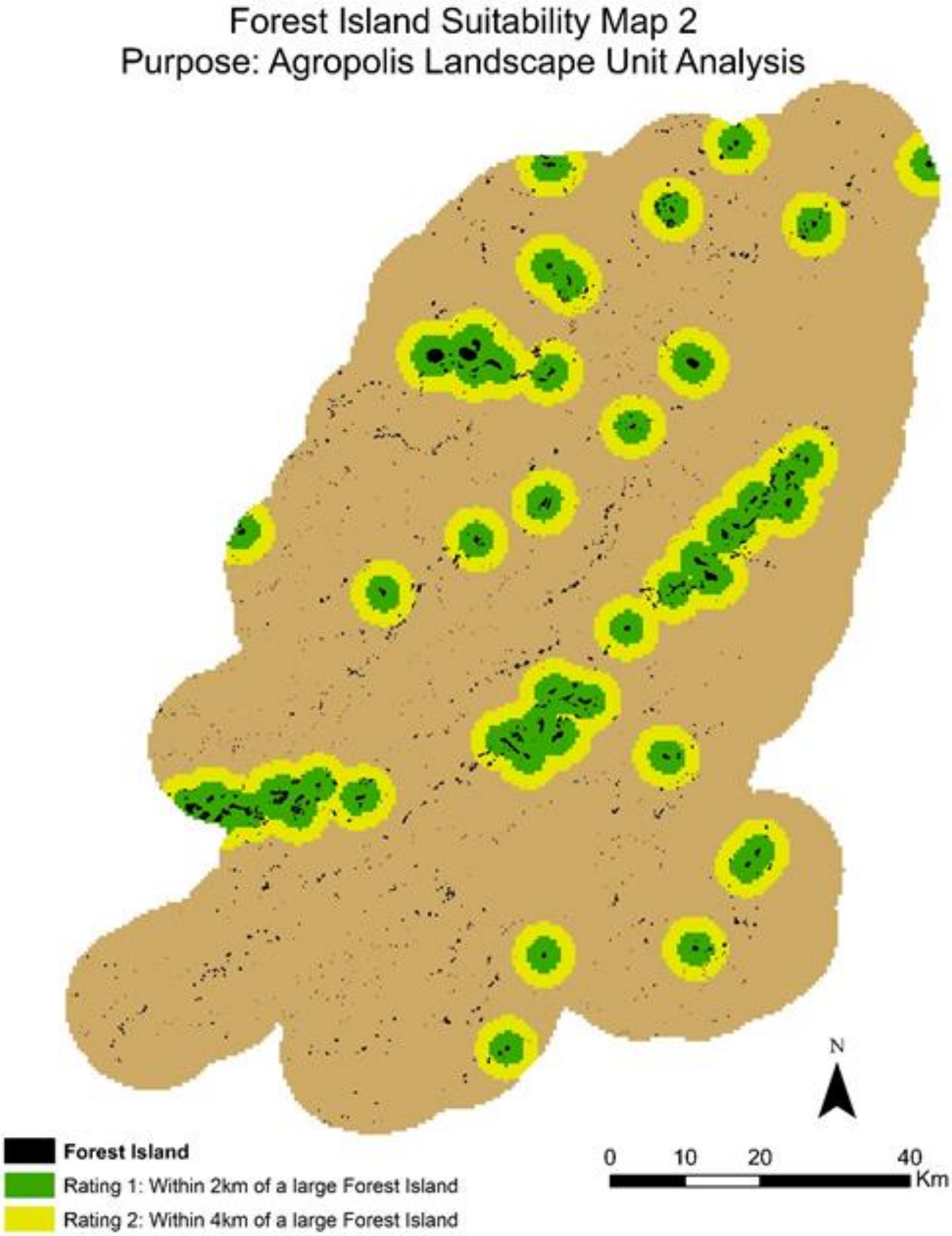


Figure 36: The purpose of Forest Island Suitability Map 2 is to rate the landscape based on proximity to large forest islands (>=26.2ha). This map is combined with Neighborhood Suitability Map 3 to create the Combined Agropolis Suitability Map.

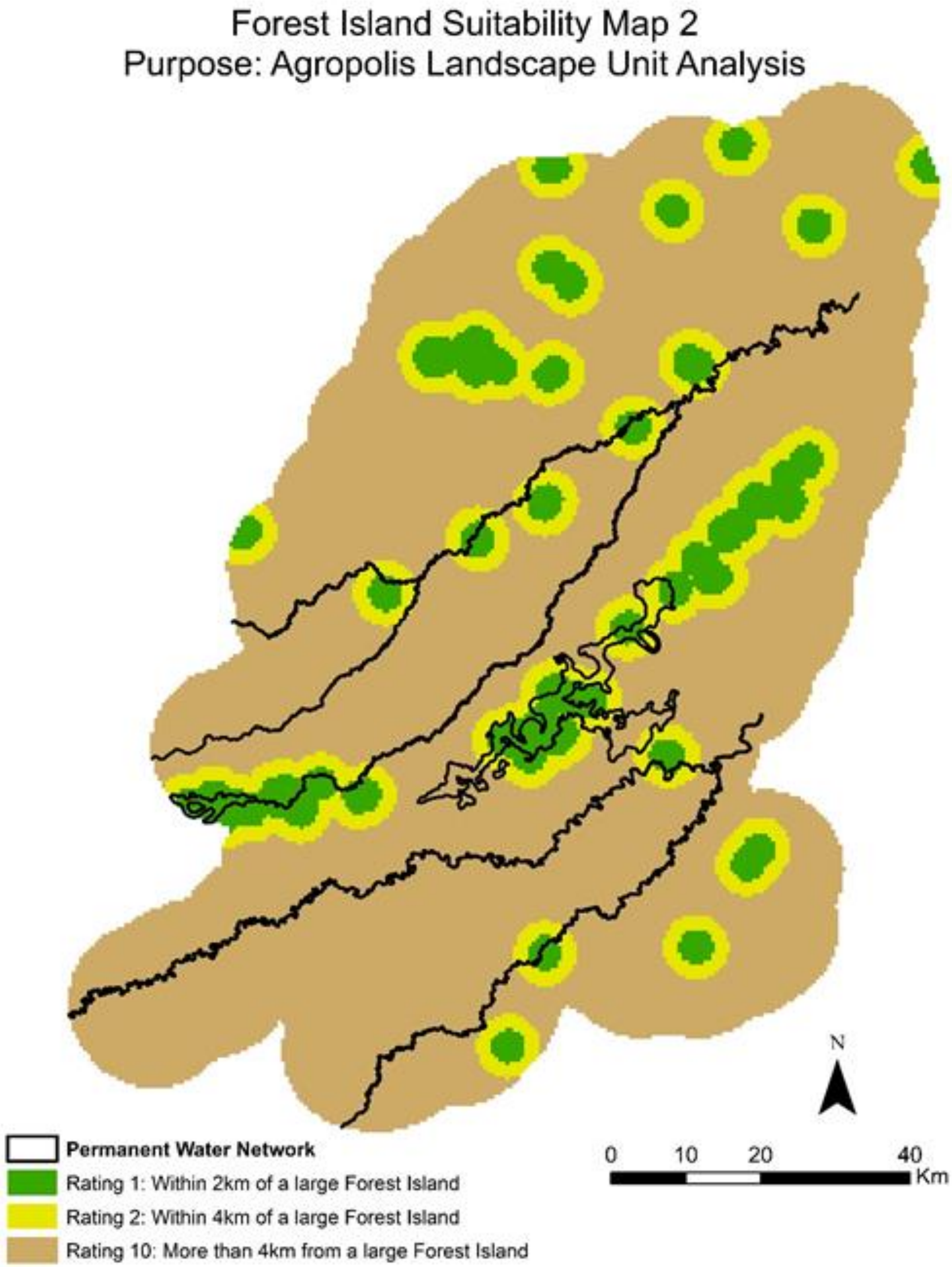


Figure 37: The purpose of Forest Island Suitability Map 2 was to rate the landscape based on proximity to large Forest Islands (>=26.2ha). This map was combined with Neighborhood Suitability Map 3 to create the Combined Agropolis Suitability Map.

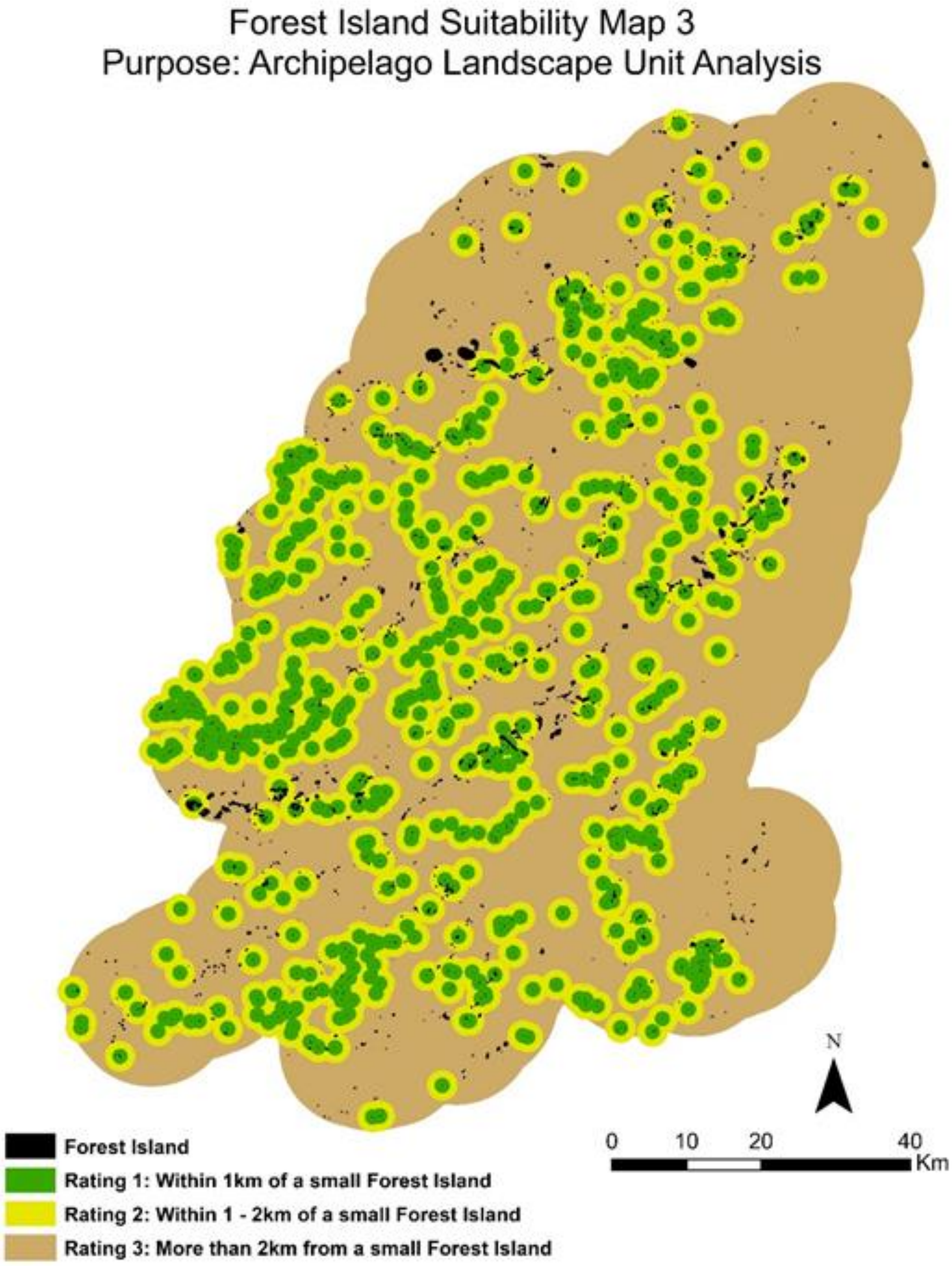


Figure 38: The purpose of Forest Island Suitability Map 3 was to rate the landscape based on proximity to small Forest Islands (<=.8ha). This map was combined with Neighborhood Suitability Map 4 to create the Combined Archipelago Suitability Map.

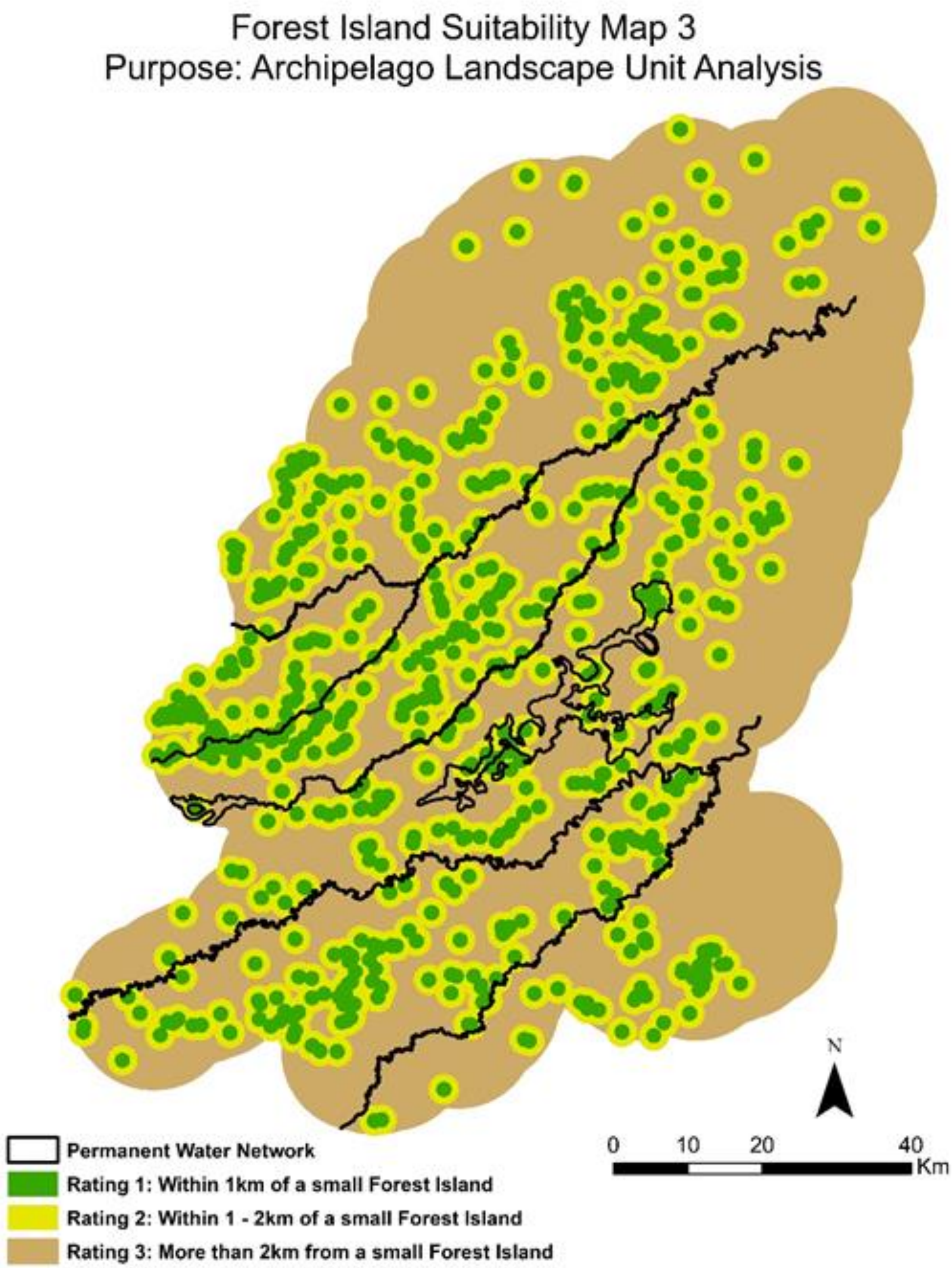


Figure 39: The purpose of Forest Island Suitability Map 3 was to rate the landscape based on proximity to small Forest Islands (<=.8ha). This map was combined with Neighborhood Suitability Map 4 to create the Combined Archipelago Suitability Map.

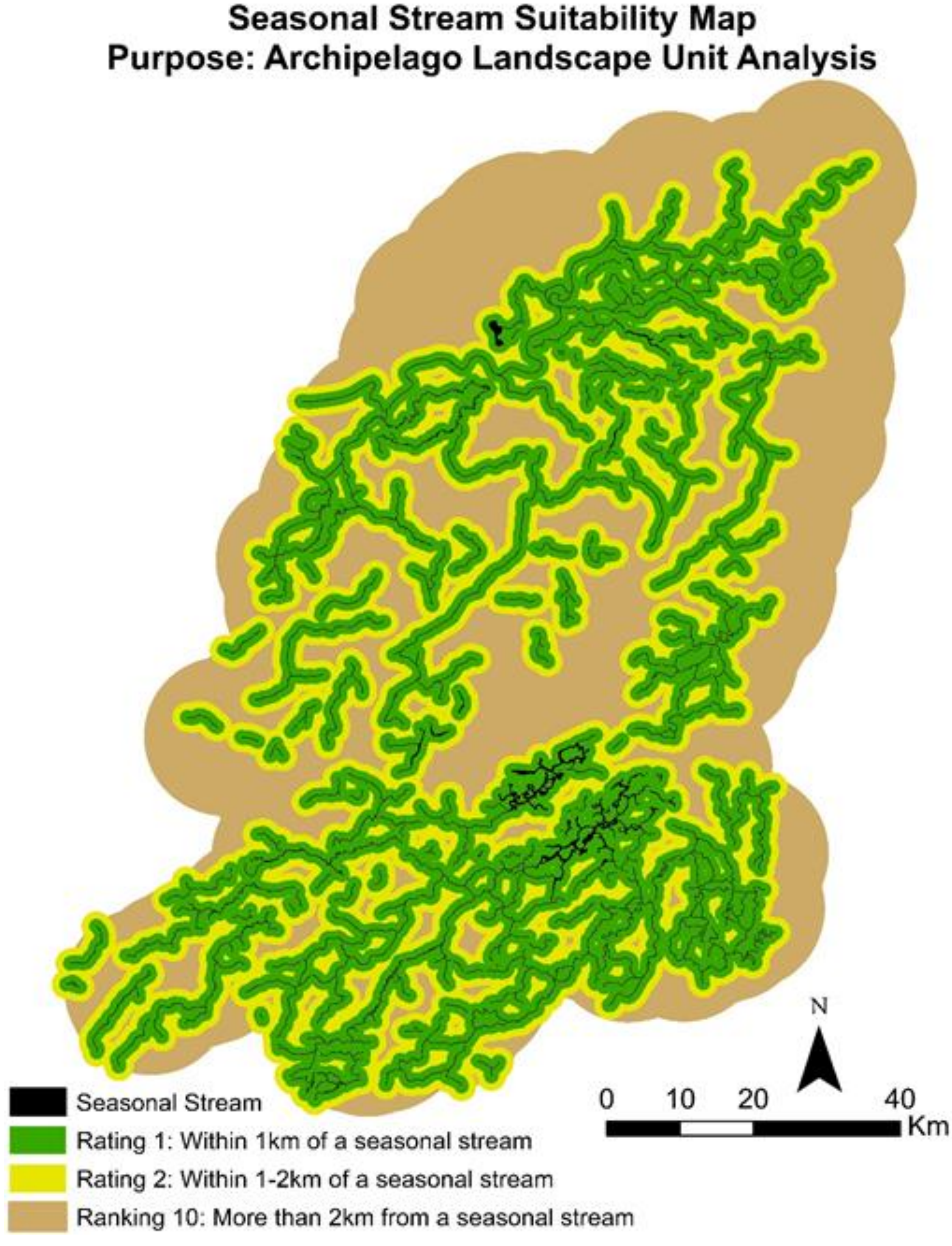


Figure 40: The purpose of the Seasonal Stream Suitability Map was to rate the landscape based on proximity to seasonal streams. This map was combined with Neighborhood Suitability Map 4 and Forest Island Suitability Map 3 to create the Combined Archipelago Suitability Map.

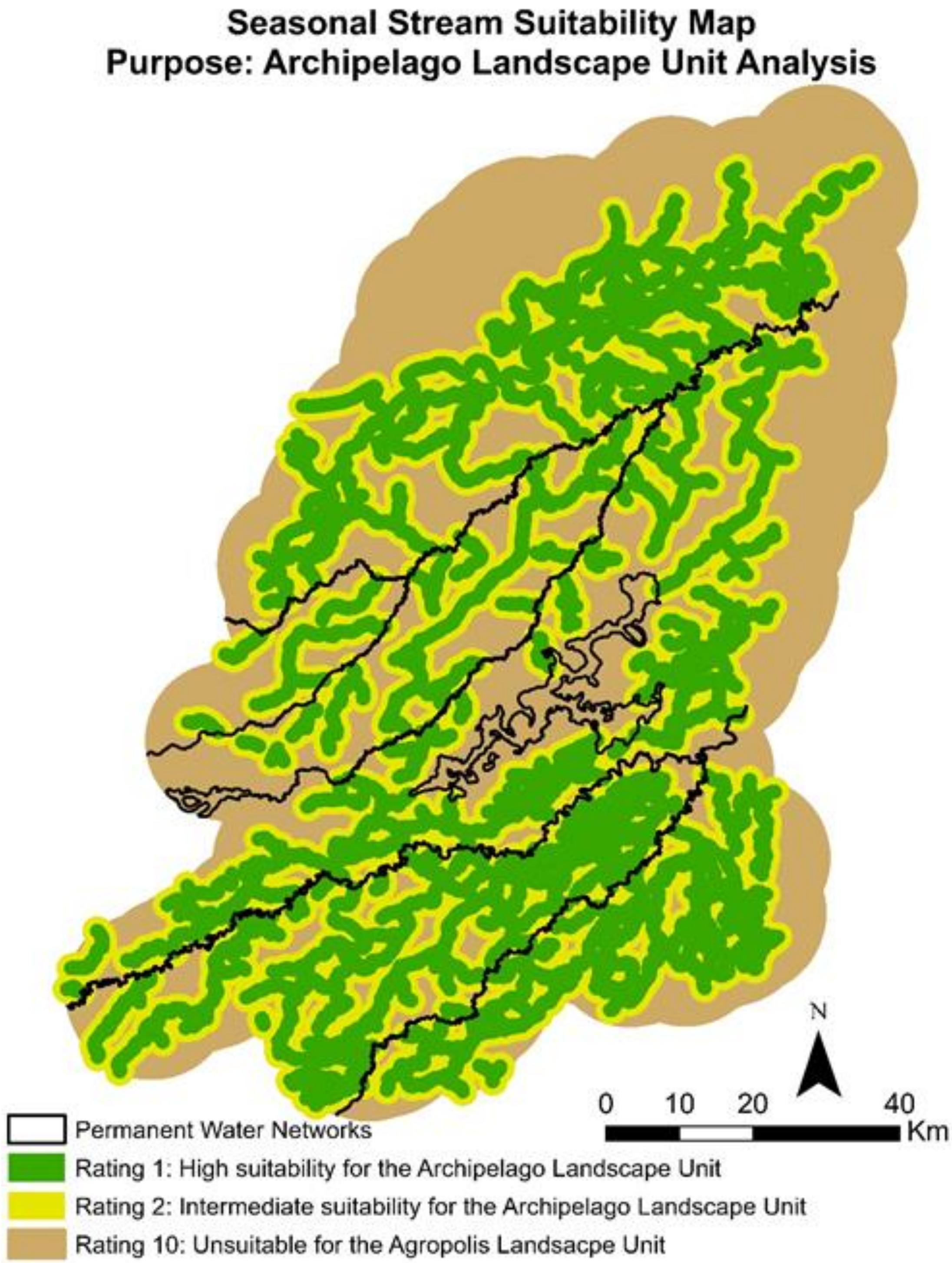


Figure 41: The purpose of the Seasonal Stream Suitability Map was to rate the landscape based on proximity to seasonal streams. This map was combined with Neighborhood Suitability Map 4 and Forest Island Suitability Map 3 to create the Combined Archipelago Suitability Map.

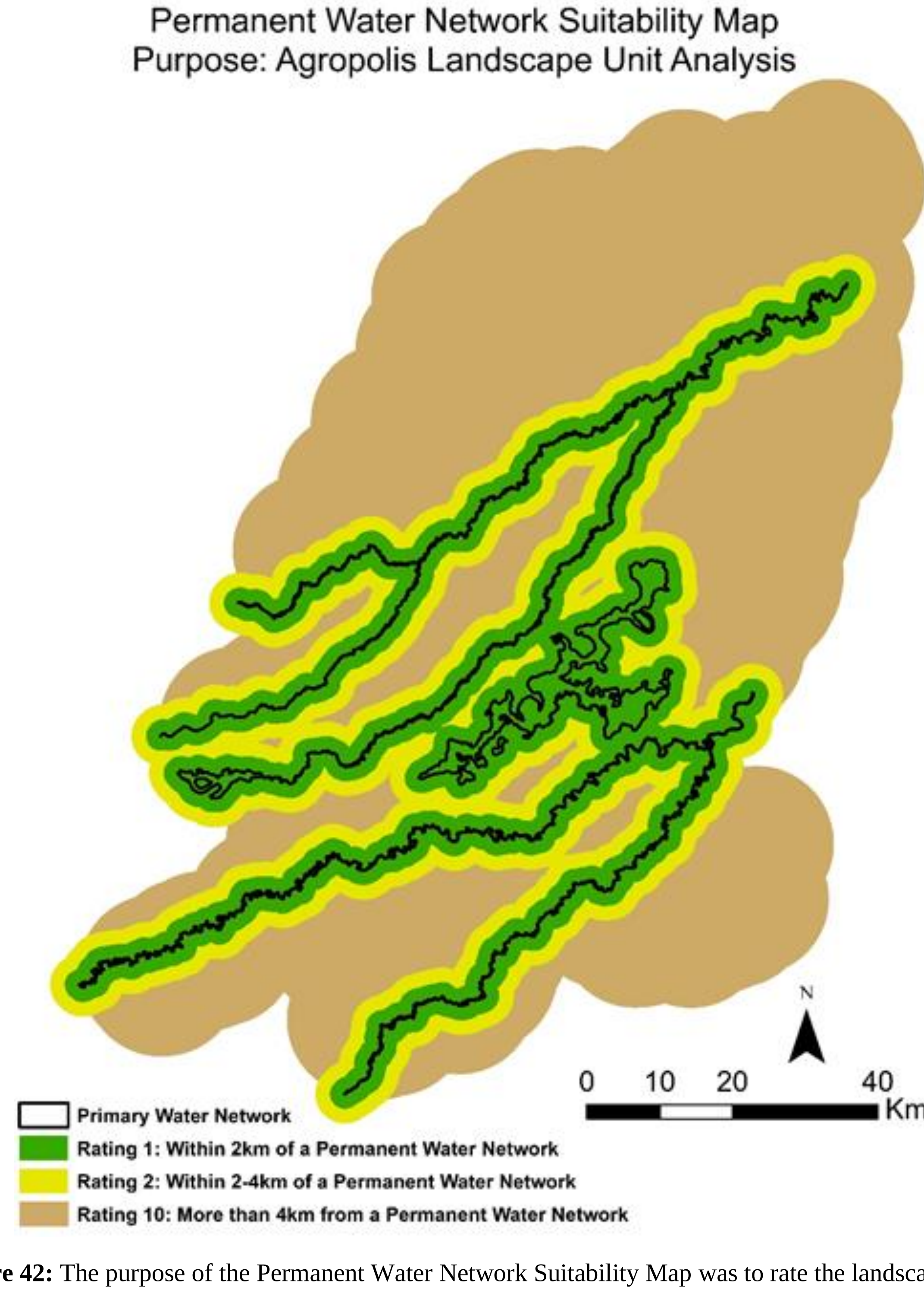


Figure 42: The purpose of the Permanent Water Network Suitability Map was to rate the landscape based on proximity to one of the 5 major permanent water networks in west Central Mojos. This map was combined with Neighborhood Suitability Map 3 and Forest Island Suitability Map 2 to create the Combined Agropolis Suitability Map.

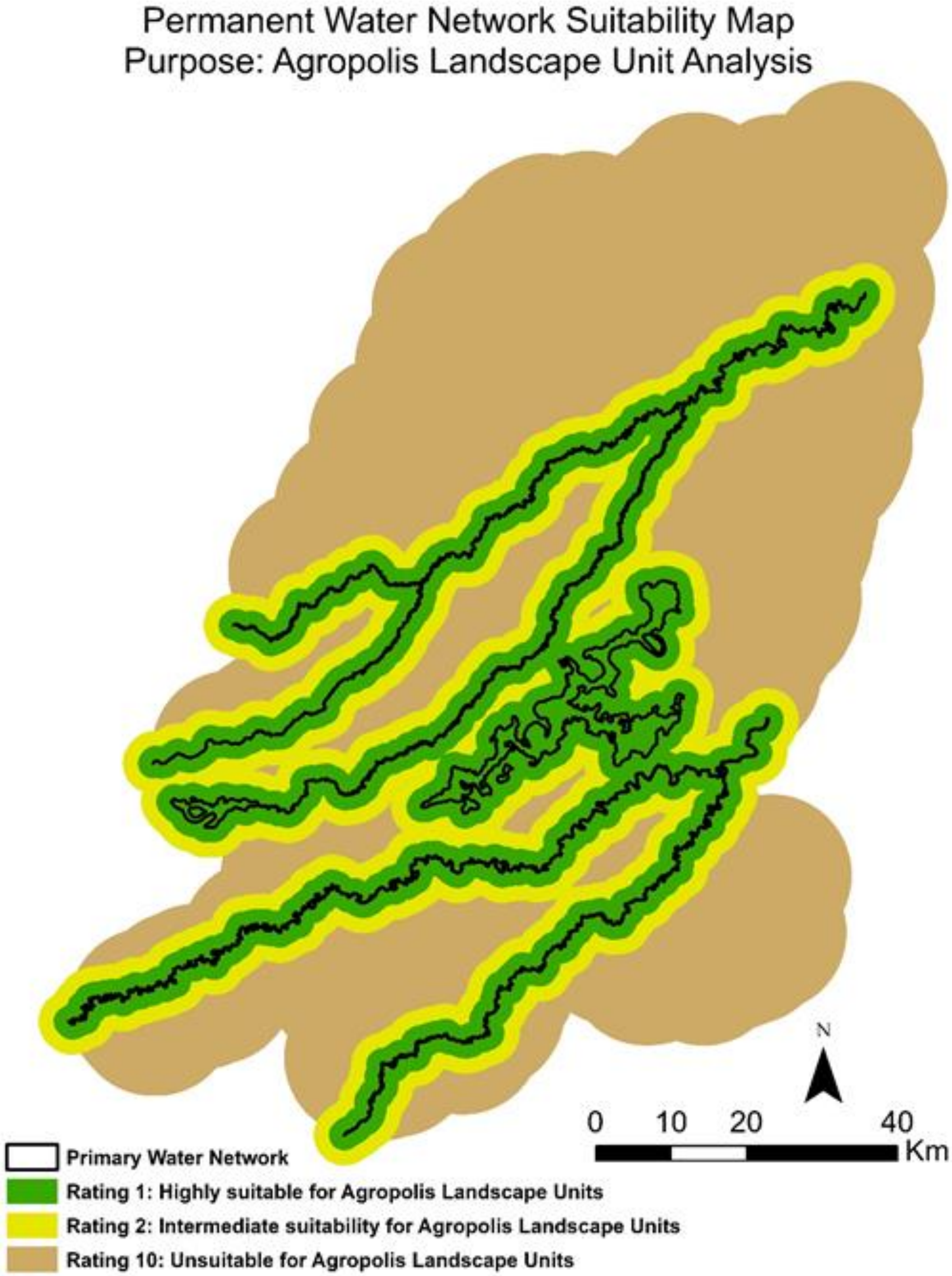


Figure 43: The purpose of the Permanent Water Network Suitability Map was to rate the landscape based on proximity to one of the 5 major permanent water networks in west Central Mojos. This map was combined with Neighborhood Suitability Map 3 and Forest Island Suitability Map 2 to create the Combined Agropolis Suitability Map.

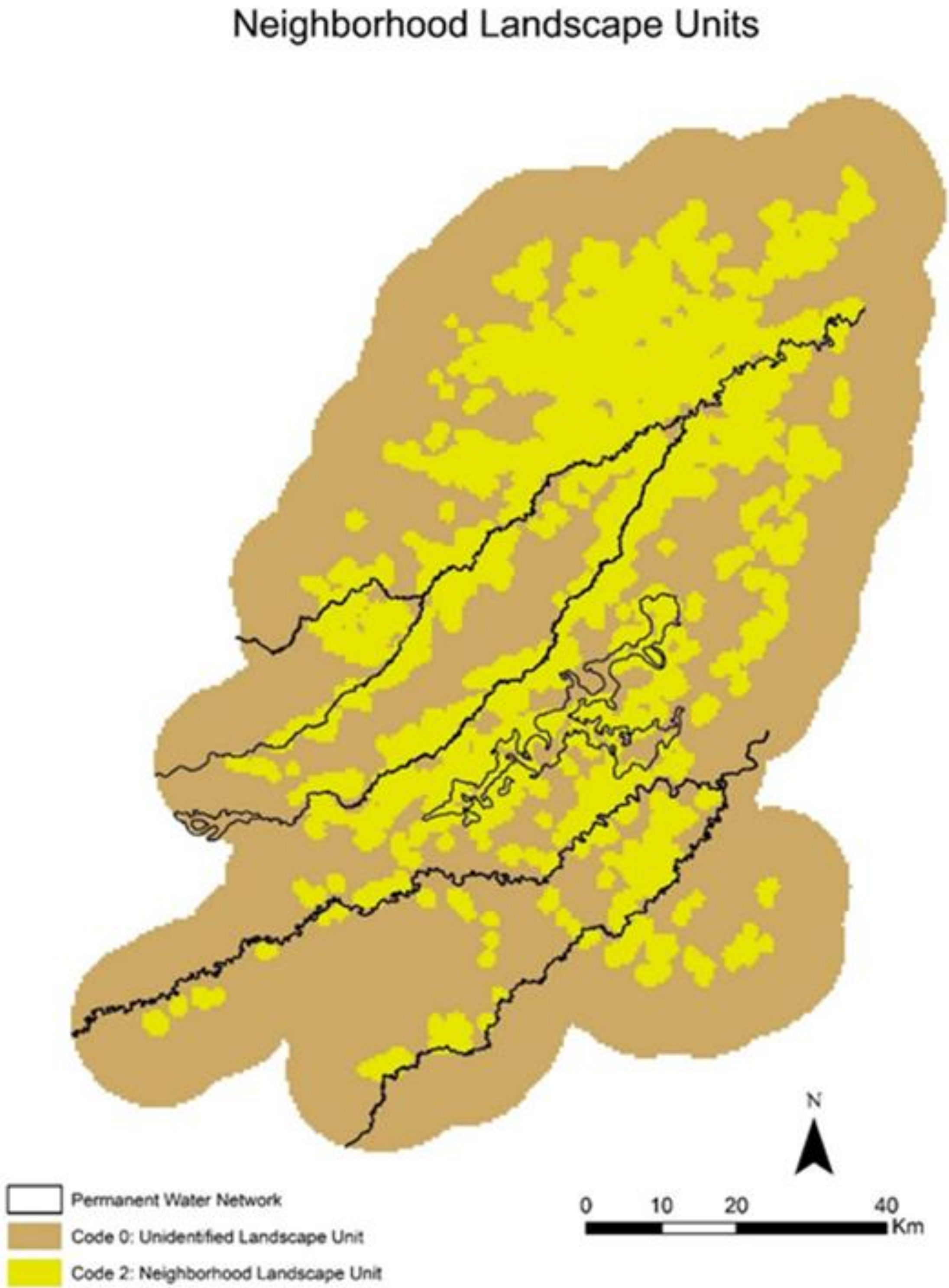


Figure 44: Neighborhood Landscape Units were derived from an interpretation of Neighborhood Suitability Map 1. Neighborhood Landscape Units represent all areas of the landscape within 1km of a raised field Neighborhood of any size. These are the areas of the landscape that most readily afford farming tasks. This map does not distinguish between Neighborhoods of different sizes.

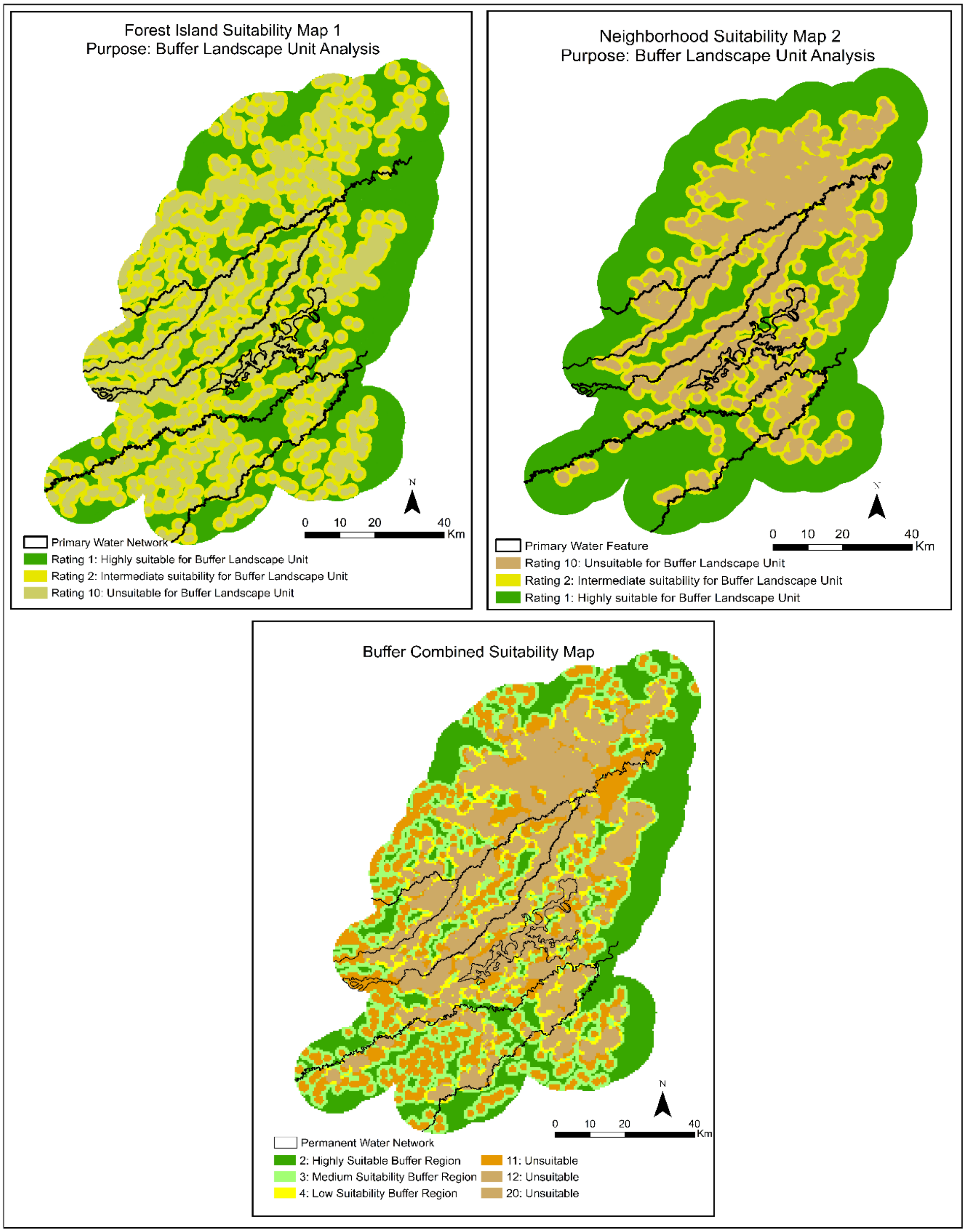


Figure 45: The Buffer Combined Suitability Map is created by combining Neighborhood Suitability Map 2 & Forest Island Suitability Map 1 using a raster calculator. Values from each raster are added together in order to determine the overall suitability of each area of the landscape for identification as a Buffer Landscape Unit. See figure 46.

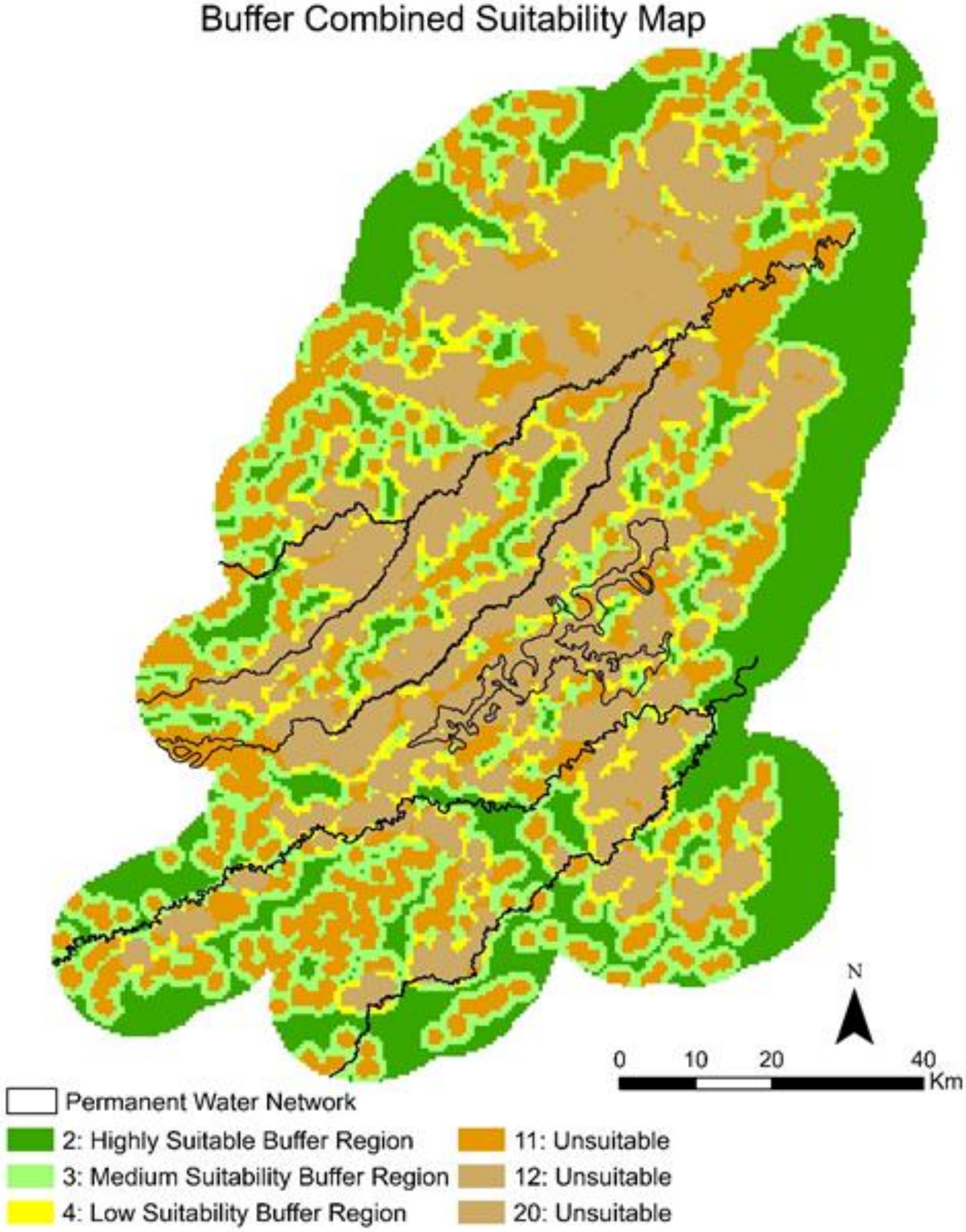


Figure 46: The Buffer Combined Suitability Map was derived from a combination of Neighborhood Suitability Map 1 & Forest Island Suitability Map 2. The purpose of the Buffer Combined Suitability Map was to provide an interpretable map from which Buffer Landscape Units were selected for further analysis. Ultimately all areas with a Ranking of 4 or lower were selected for the Buffer Landscape Unit Map.

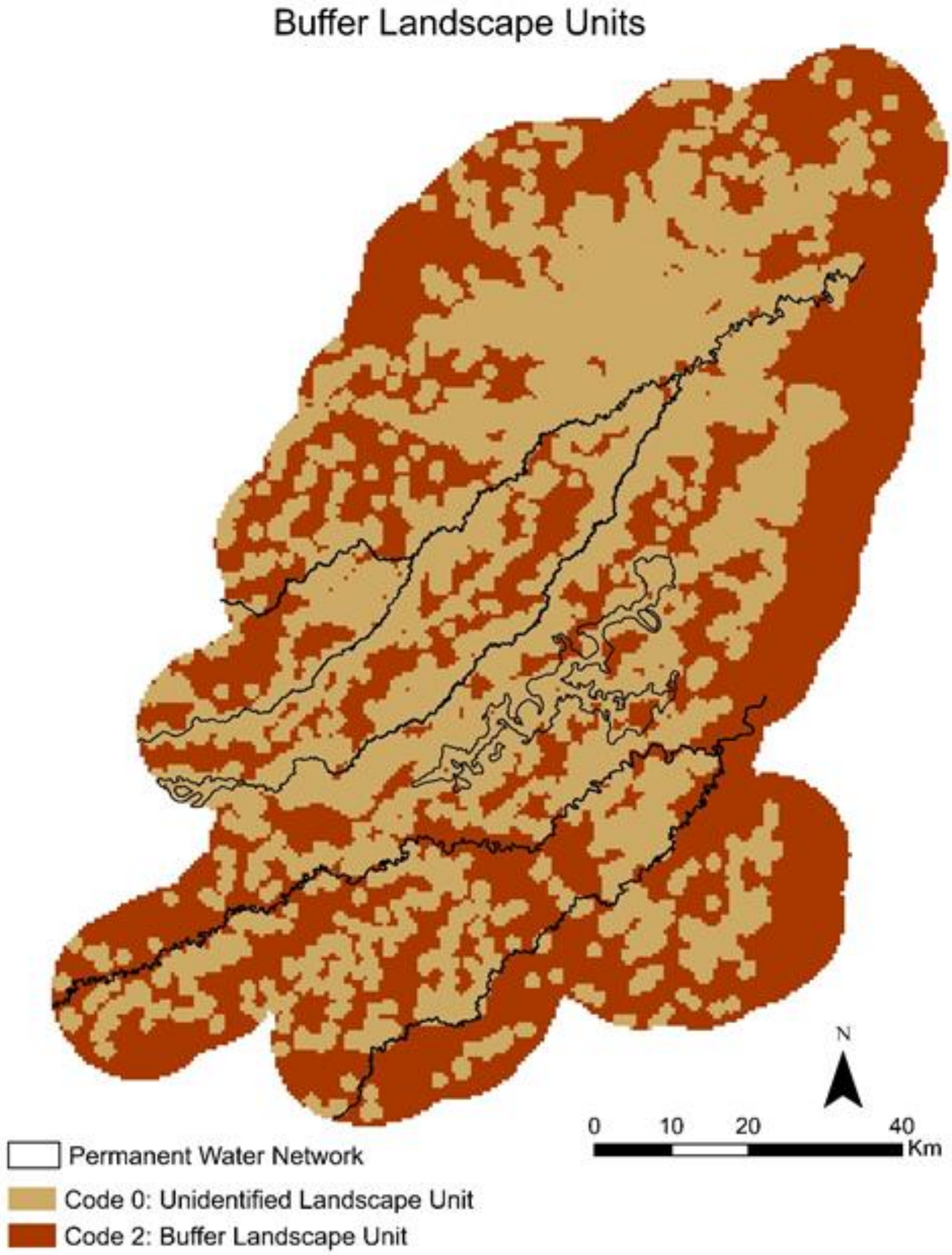


Figure 47: Buffer Landscape Units were derived from an interpretation of the Combined Buffer Suitability Map. Buffer Landscape Units represent all areas of the landscape with a combined distance of at least 3 kilometers to the nearest Forest Island & raised field Neighborhood but is not within 1km of either a Forest Island or raised field Neighborhood.

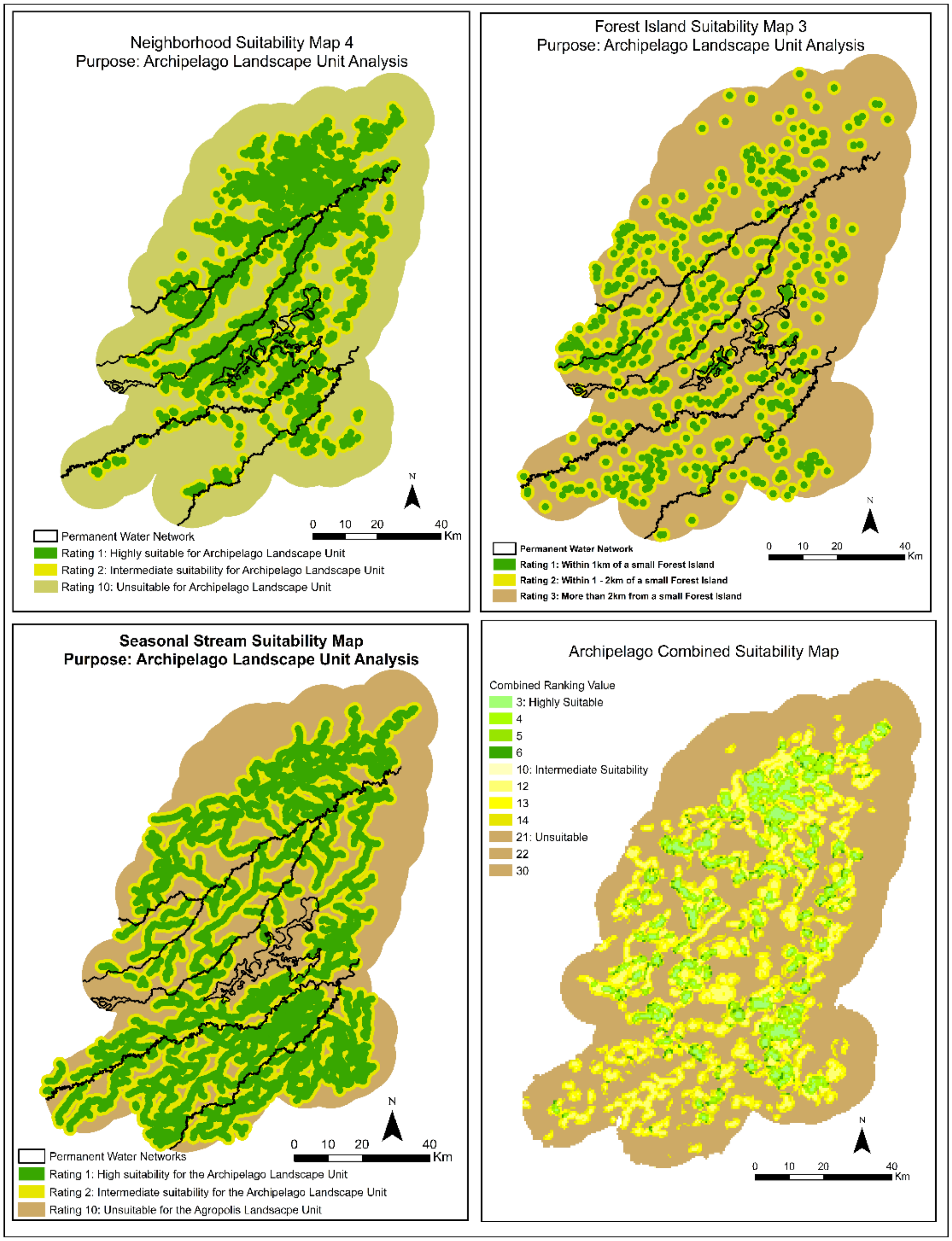


Figure 48: The Archipelago Combined Suitability Map was derived from a combination of Neighborhood Suitability Map 4, Forest Island Suitability Map 3 & the Seasonal Water Network Suitability Map. The purpose of the Archipelago Combined Suitability Map was to provide an interpretable map from which Archipelago Landscape Units were selected for further analysis.

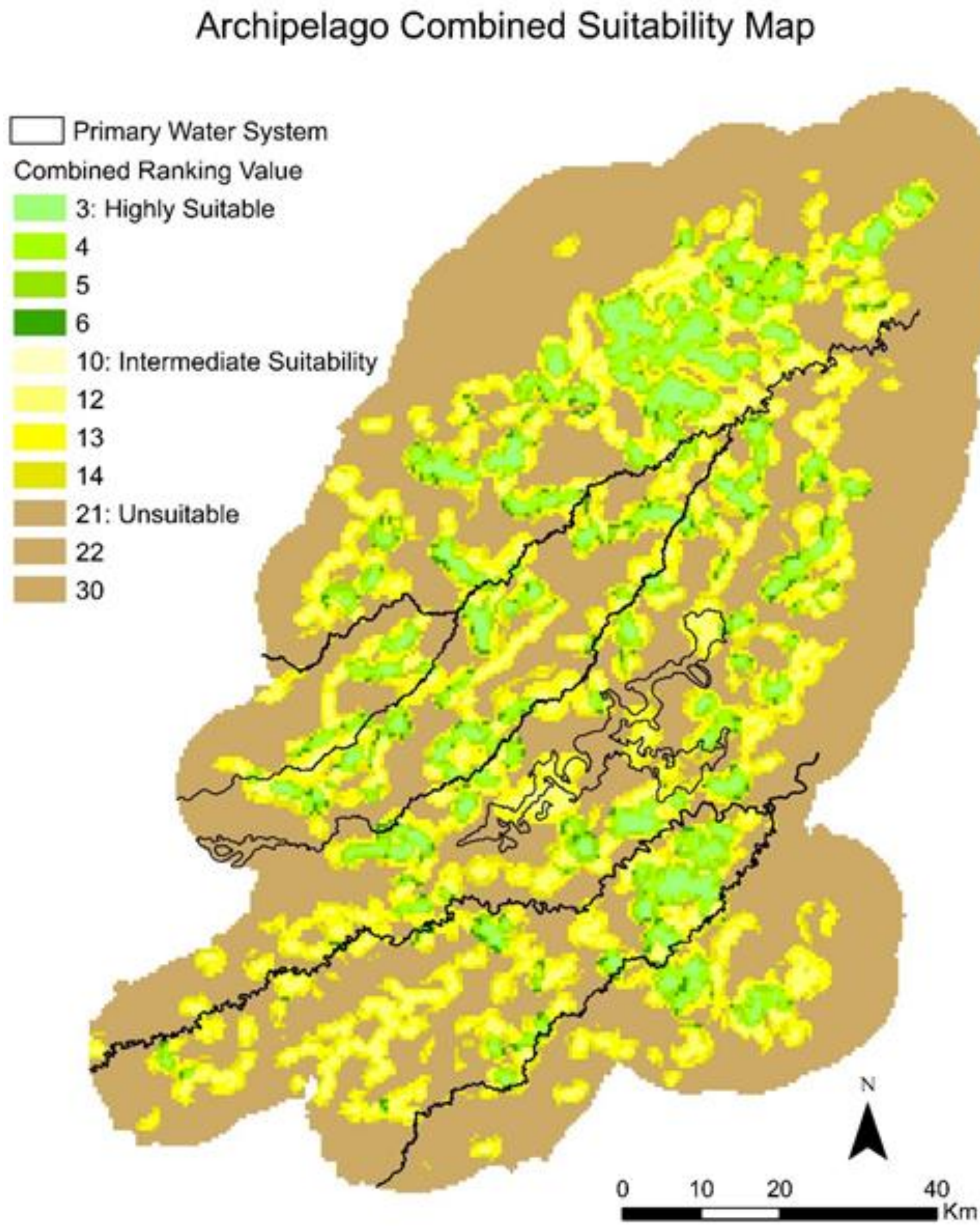


Figure 49: The Archipelago Combined Suitability Map was derived from a combination of Neighborhood Suitability Map 4, Forest Island Suitability Map 3 & the Seasonal Water Network Suitability map. The purpose of the Archipelago Combined Suitability Map was to provide an interpretable map from which Archipelago Landscape Units were selected for further analysis. Ultimately all areas with a Ranking of 12 or lower were selected for the Archipelago Landscape Unit Map.

Figure 50: There are several ways to interpret the Archipelago Combined Suitability Map. A value of 12 was selected as the cutoff for this map given the tendency for this value to link up a large number of Archipelago chains on the map while still leaving a great deal of regional variation.

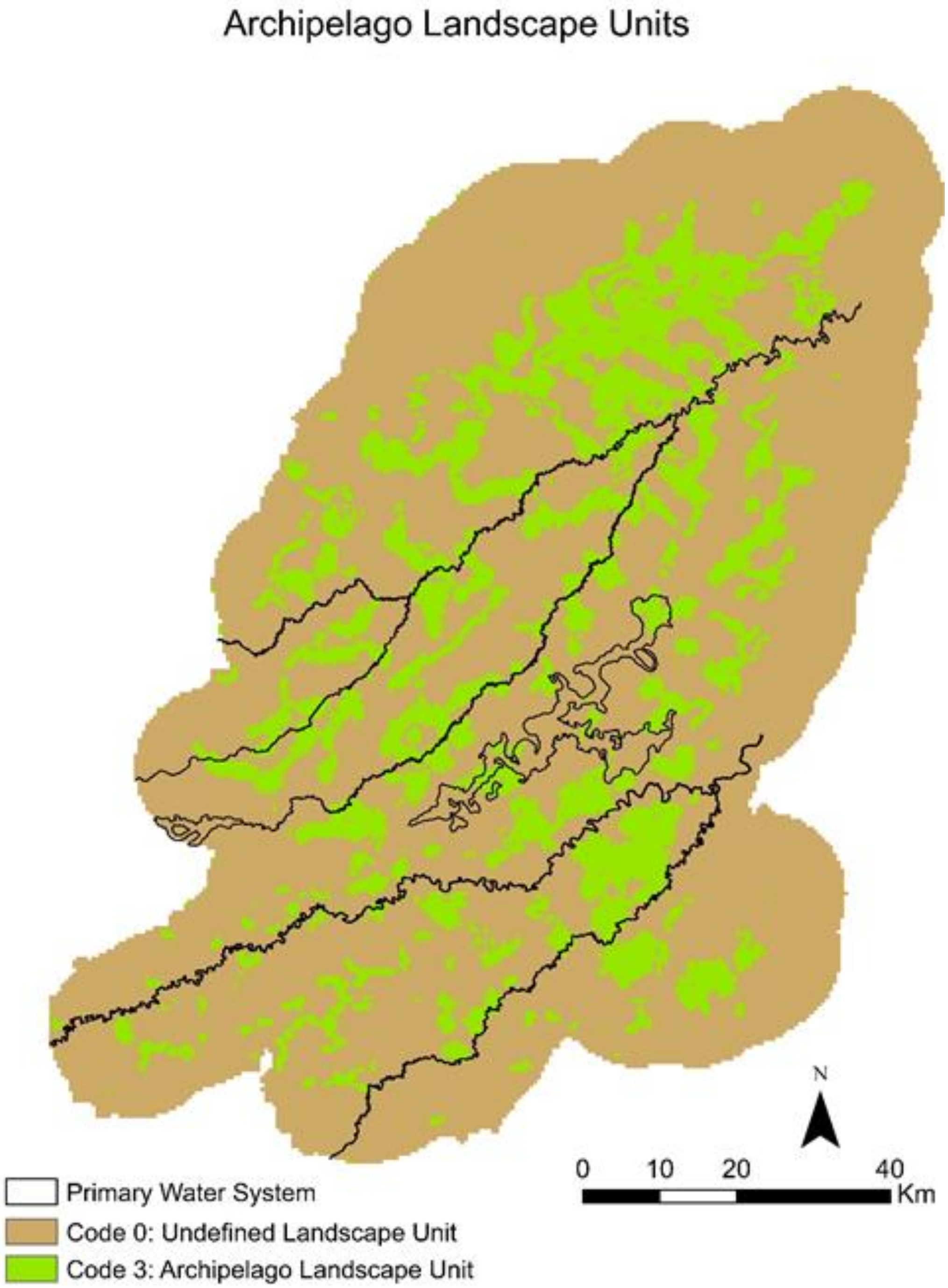


Figure 51: Archipelago Landscape Units were derived from an interpretation of the Combined Archipelago Suitability Map. Archipelago Landscape Units represent all areas of the landscape that meet three sets of criteria: located within 1 kilometer of a seasonal stream, within 2 kilometers of a raised field Neighborhood containing less than 90 individual platforms, and within 2 kilometers of a small forest island less than or equal to 0.8ha in size.

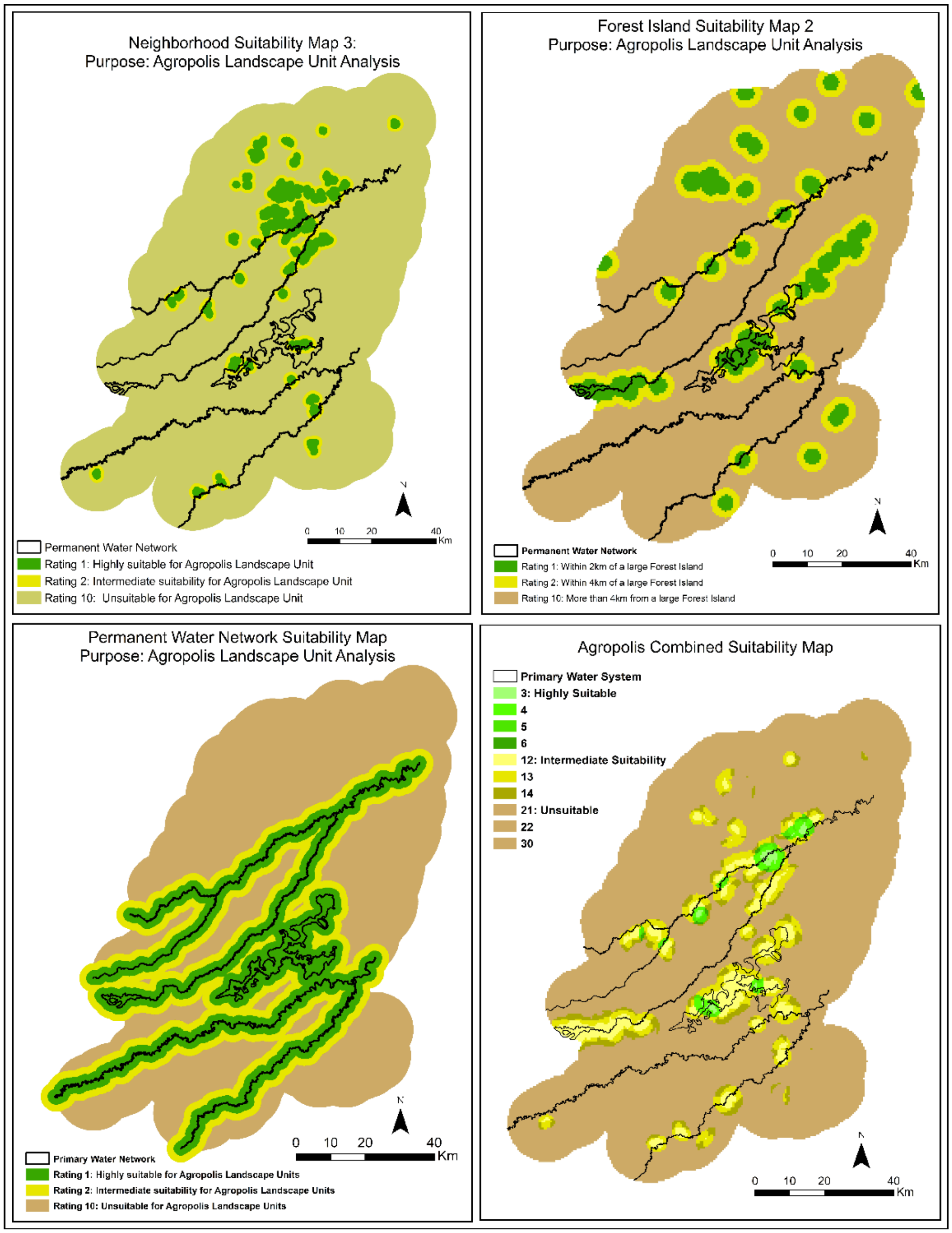


Figure 52: The Agropolis Combined Suitability Map was derived from a combination of Neighborhood Suitability Map 3, Forest Island Suitability Map 2 & the Permanent Water Network Suitability Map. Values from each of the first three suitability maps are summed together to create a combined suitability ranking for that portion of the landscape. The purpose of the Agropolis Combined Suitability Map was to provide an interpretable map from which Agropolis Landscape Units were selected for further analysis.

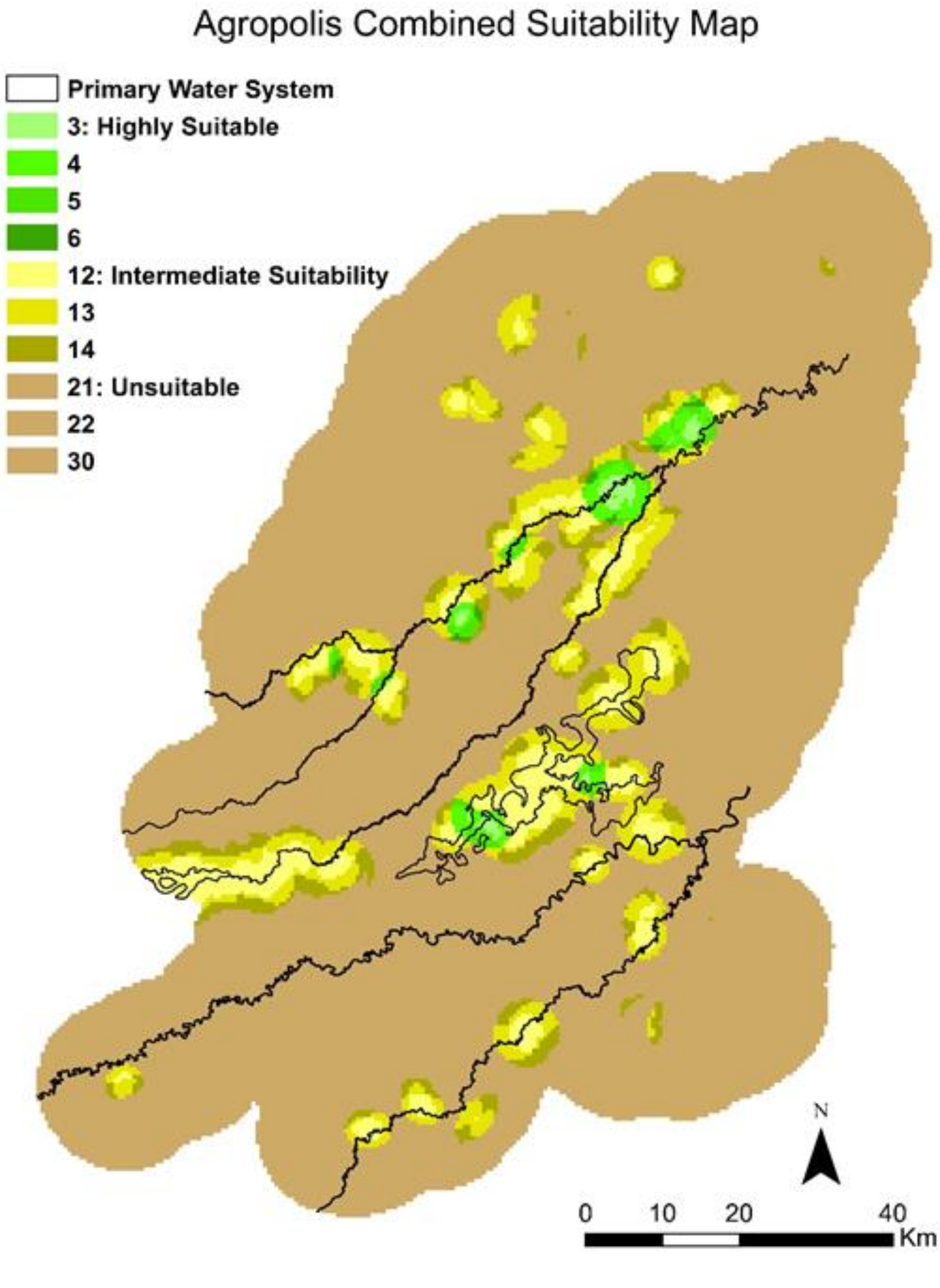


Figure 53: The Agropolis Combined Suitability Map was derived from a combination of Neighborhood Suitability Map 3, Forest Island Suitability Map 2 & the Permanent Water Network Suitability Map. The purpose of the Agropolis Combined Suitability Map was to provide an interpretable map from which Agropolis Landscape Units were selected for further analysis.

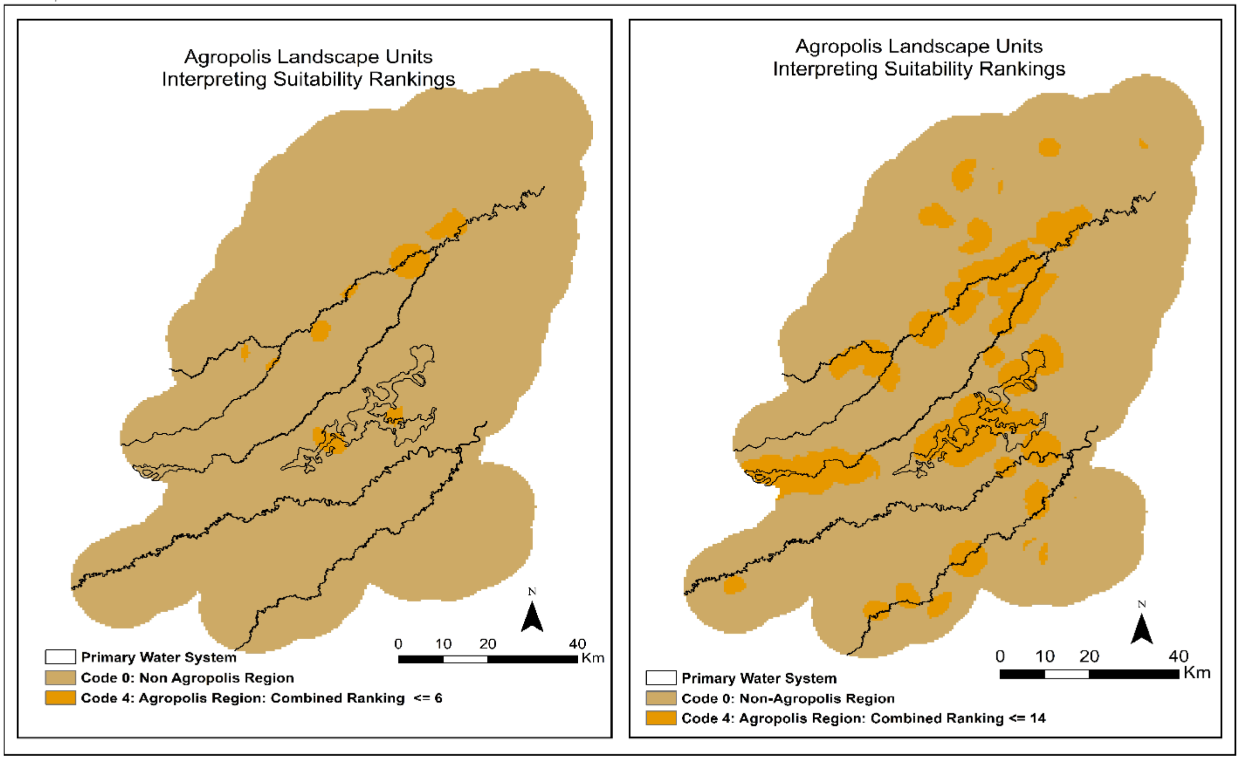


Figure 54: The purpose of the Agropolis Combined Suitability Map was to provide an interpretable map from which Agropolis Landscape Units may be selected for further analysis. Ultimately all areas with a Ranking of 6 or lower were selected for the Agropolis Landscape Unit Map. This cutoff value excludes any portions of the landscape that received an unsuitable (10) ranking in any area of the suitability maps.

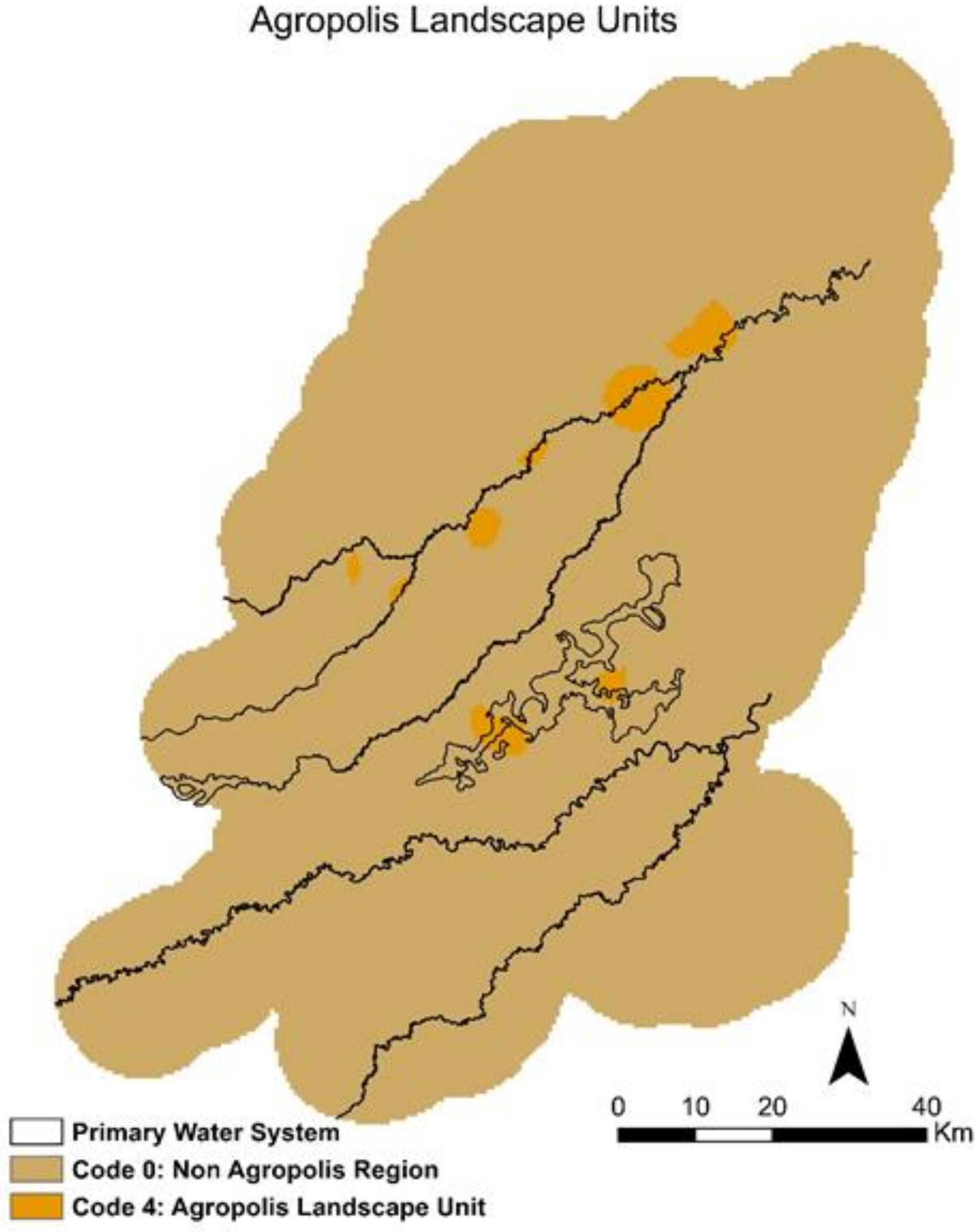


Figure 55: Agropolis Landscape Units were derived from an interpretation of the Combined Agropolis Suitability Map. Agropolis Landscape Units represent all areas of the landscape that meet three sets of criteria: located within 4 kilometers of a permanent water network, within 2 kilometers of a large raised field Neighborhood containing more than 90 individual platforms, and within 4 kilometers of a large forest island greater than or equal to 22.6ha in size.

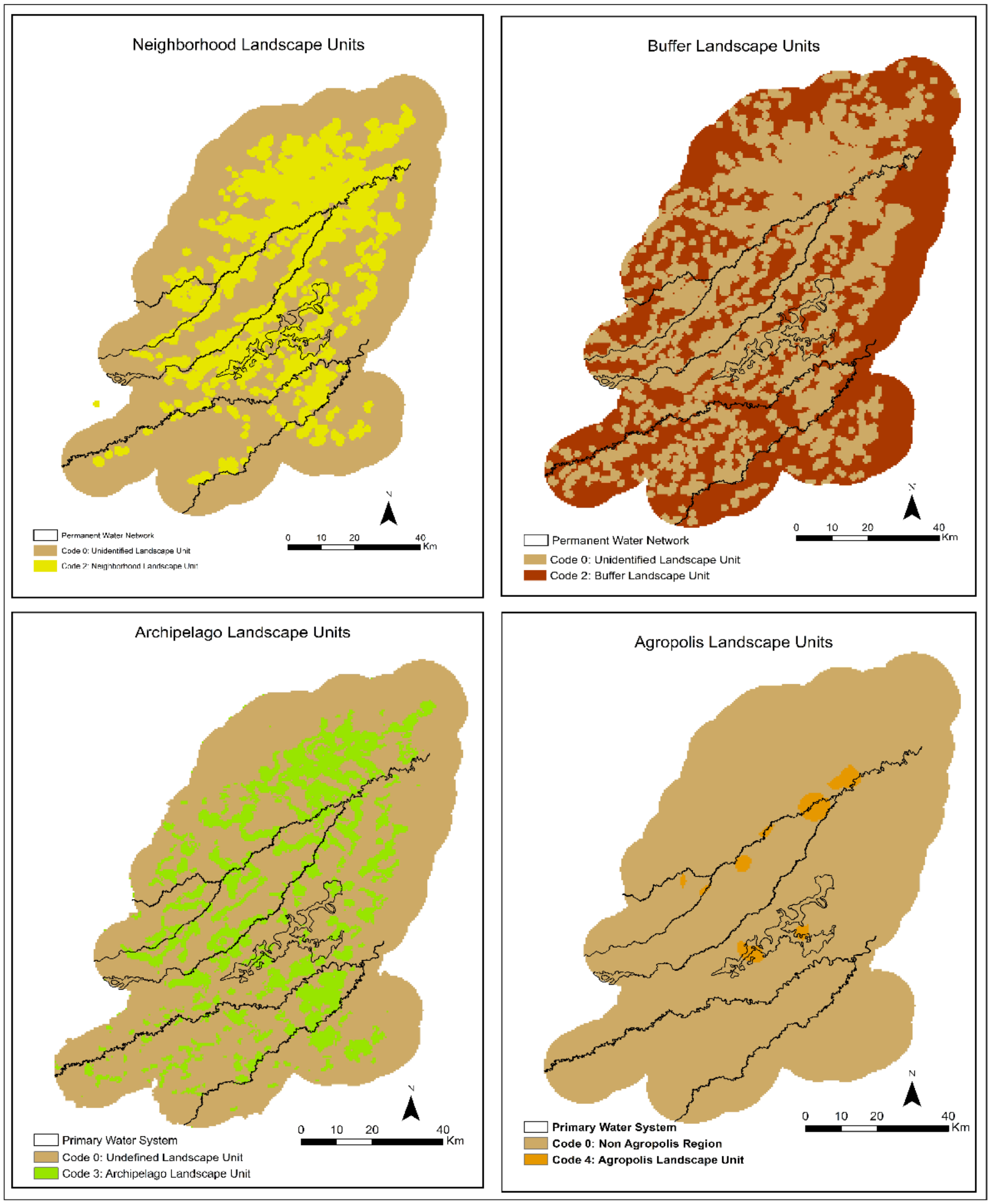


Figure 56: Once all four Landscape Unit Maps were created, each map was assigned an individual code to represent that specific Landscape Unit. The purpose of these codes was so that all four of the Landscape Units could be combined into a single map and their distribution in relation to and intersection with one another can be examined. See Figure 57.

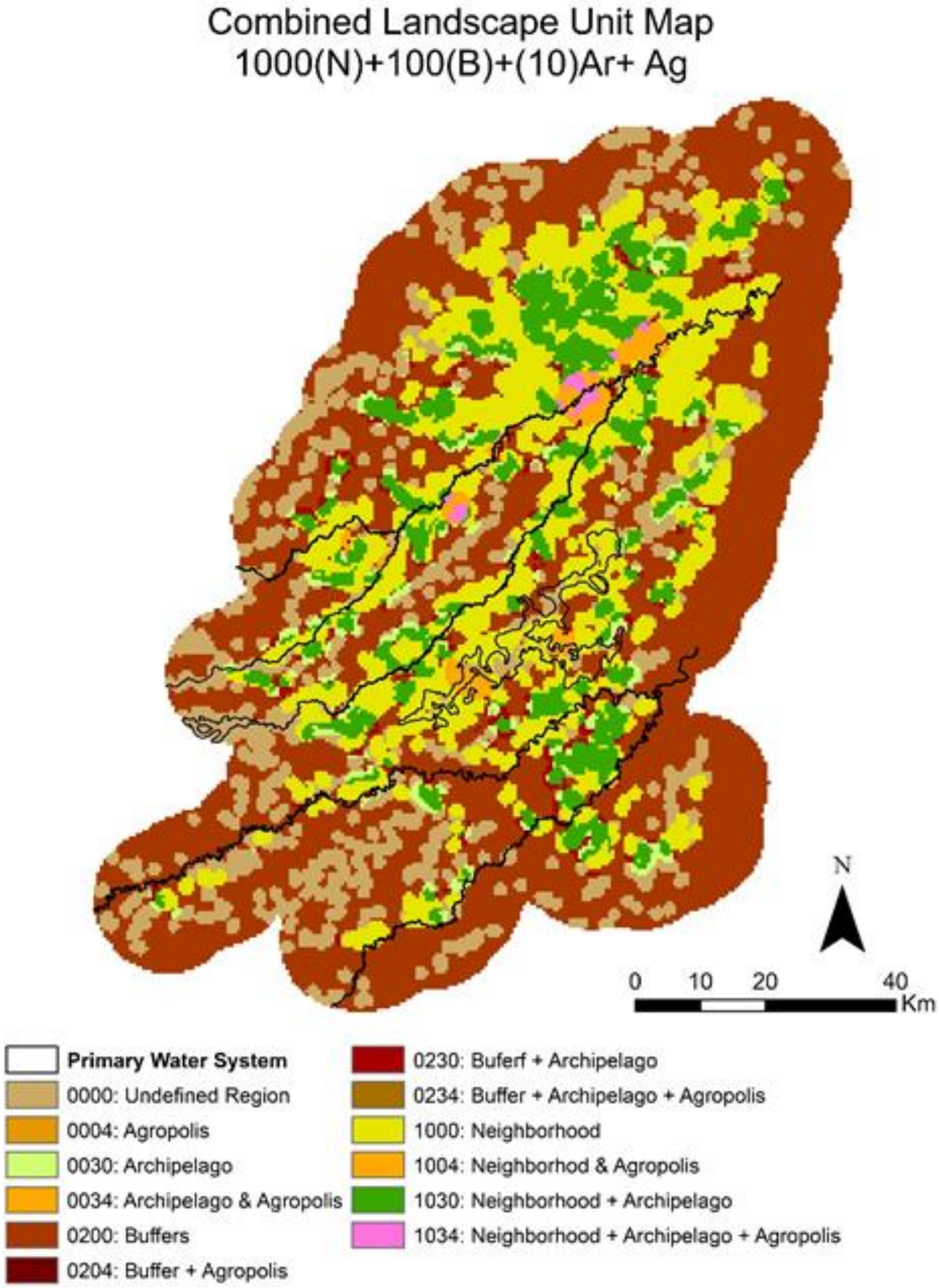


Figure 57: The Combined Landscape Unit Map is created by combining each of the four Landscape Unit Maps together with a raster calculator. The first digit in the resulting code represents whehter or not a Neighborhood Landscape Unit intersected with that cell of the raster. A 0 for a first digit means no Neighborhoods were present. A 1 in the first digit means that Neighborhoods were present. Combinations of numbers mean that combinations of Landscape Units are overlapping in that cell. Of interest in this map is the code 0000 which are the unidentified regions of the landsacpe which did not have either a Neighborhood, Buffer, Archipelago, or Agropolis Landscape Unit identified.

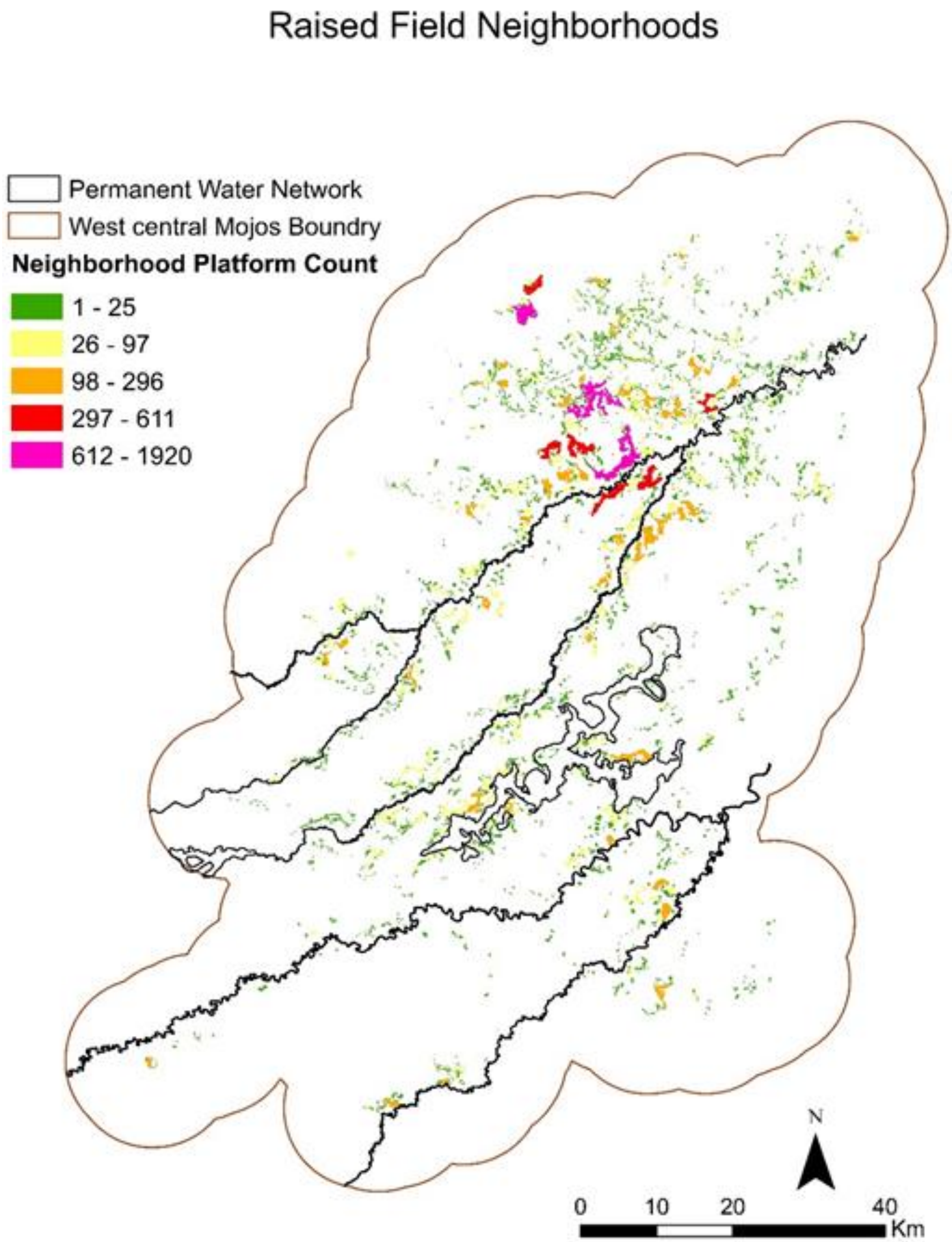
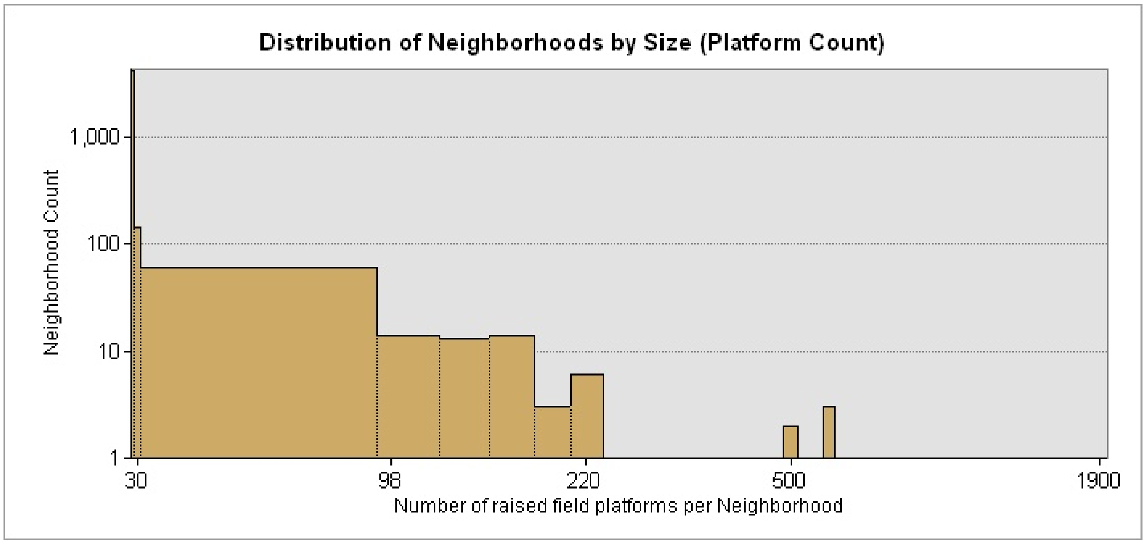


Figure 58: A total of 44,224 raised field platforms were organized into 4,444 raised field Neighborhoods. To be in the same Neighborhood, platforms must be within 40m of at least one other platform in the same Neighborhood. Platforms were not assigned to more than 1 Neighborhood.



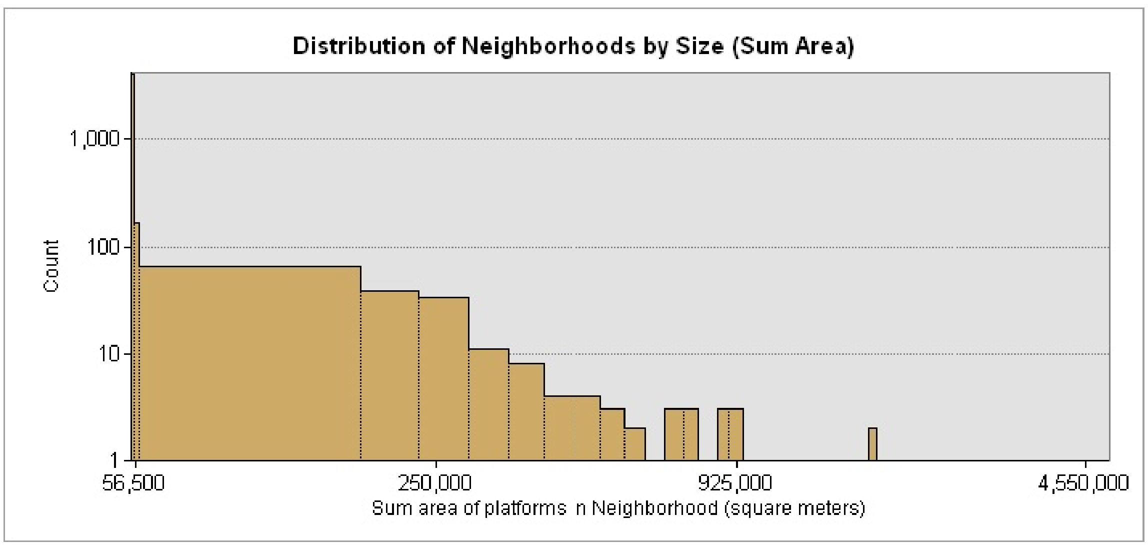
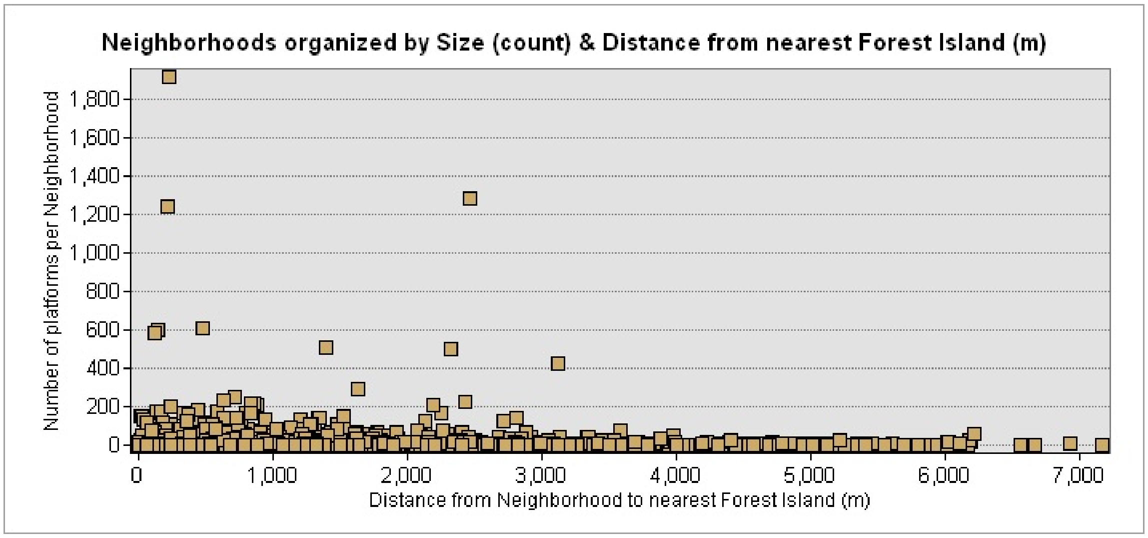


Figure 59: These charts demonstrate the distribution of raised field Neighborhoods by their total size. **(Top)** Neighborhood size is measured by the number of platforms in a Neighborhood. **(Bottom)** Neighborhood size is measured by the total surface area of all platforms in the Neighborhood.



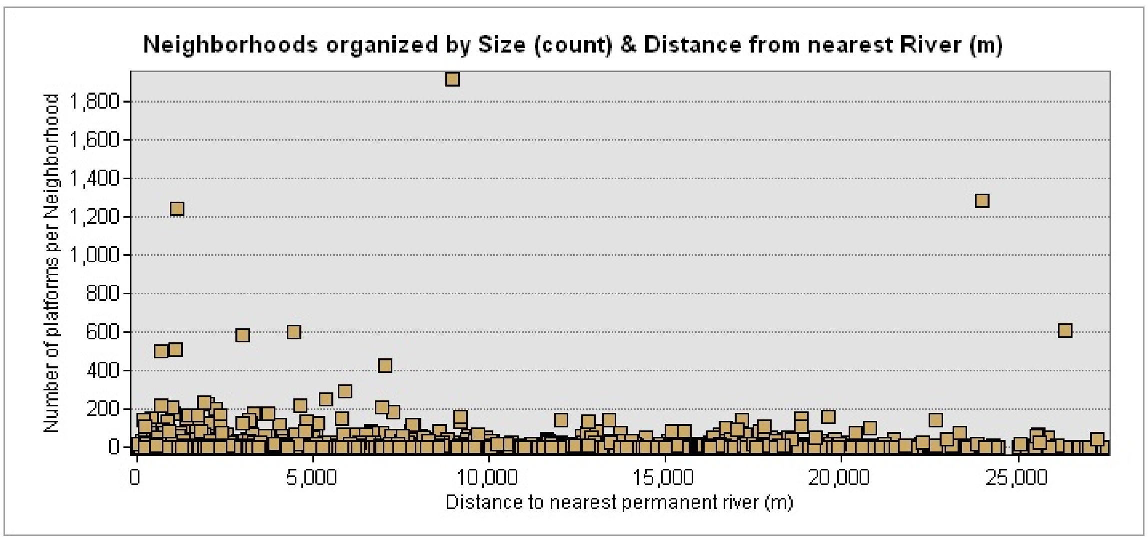
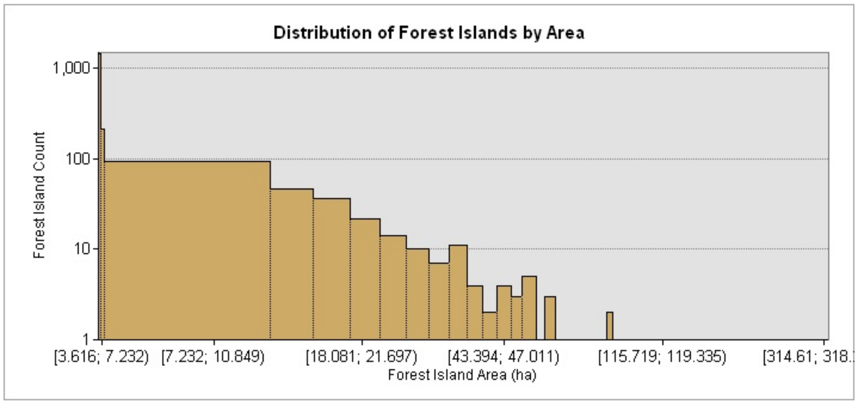


Figure 60: The size of a Neighborhood is compared to its distance from the nearest forest Iisland as well as distance to the nearest permanent flowing river. Neighborhoods of any size are consistently found at any distance from the river. The largest Neighborhoods are consistently found less than 3km from a forest island.



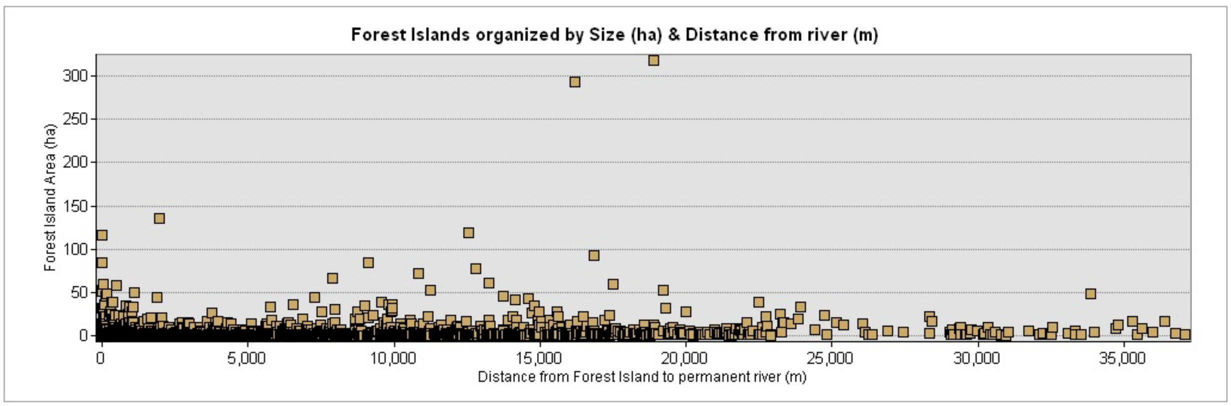
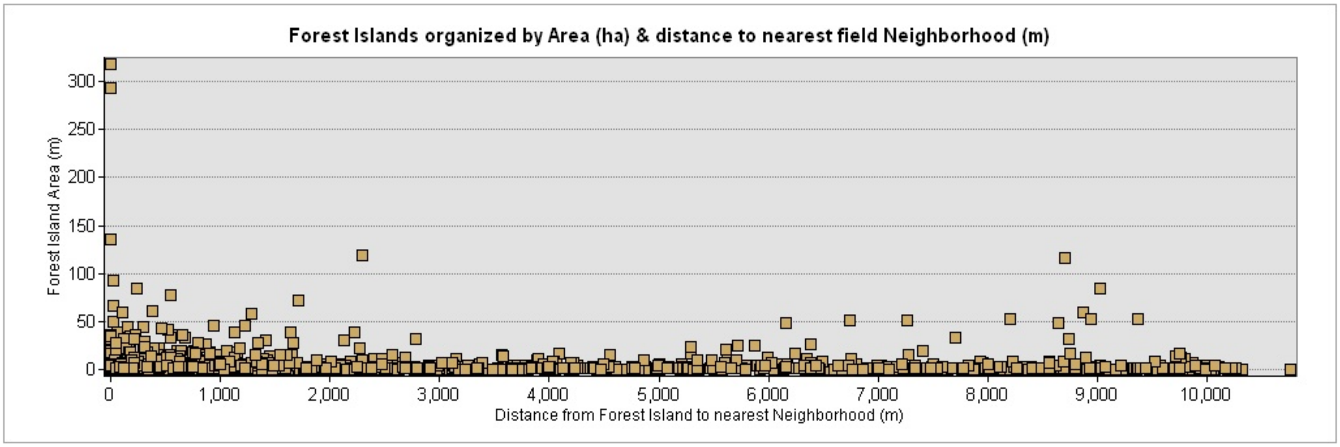


Figure 61: (Top) This chart demonstrates that the number of forest islands of a given size decreases as the size of the forest island increases. There are far more small forest islands than large forest islands. **(Bottom)** Large forest islands are clustered in groups within 2km of the river and then again between 10 to 20km. These large forests islands more than 10km from a permanent river are located along the northern limit of the study area near the Tapado river and its associated wetlands.



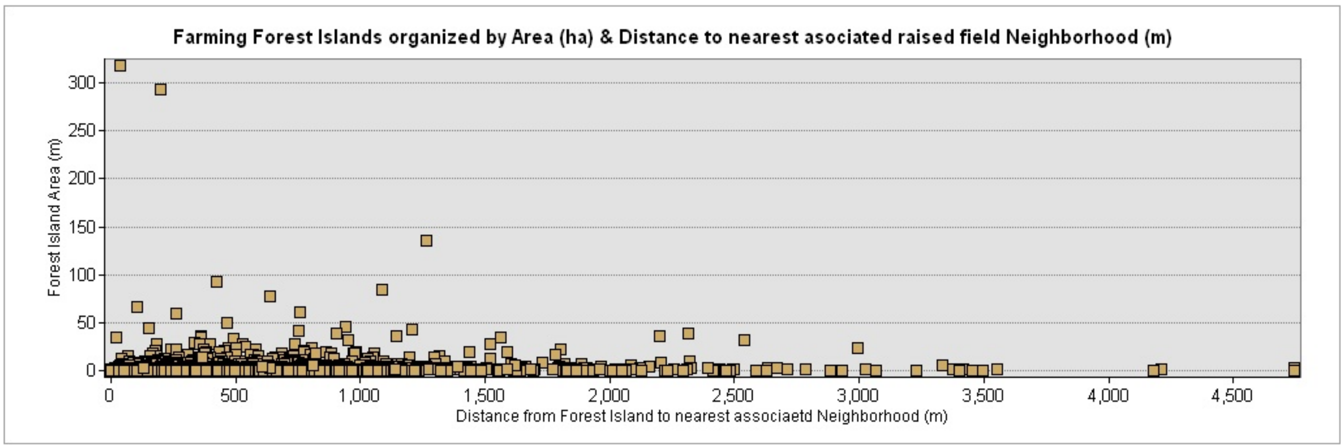


Figure 62: (Top) These charts compare the size of a forest island to its distance to the nearest raised field Neighborhood. **(Bottom)** Each raised field platform had its nearest forest island identified. These forests were identified as farming forests and their average distances to Neighborhoods measured separately from the rest of the population of forest islands. This comparison is meant to highlight that it is difficult to associate a raised field platform with only a single forest island. However, while there are many forest islands at great distances from a raised field, there are few raised fields that are not within 2 to 3 kilometers of a forest island.

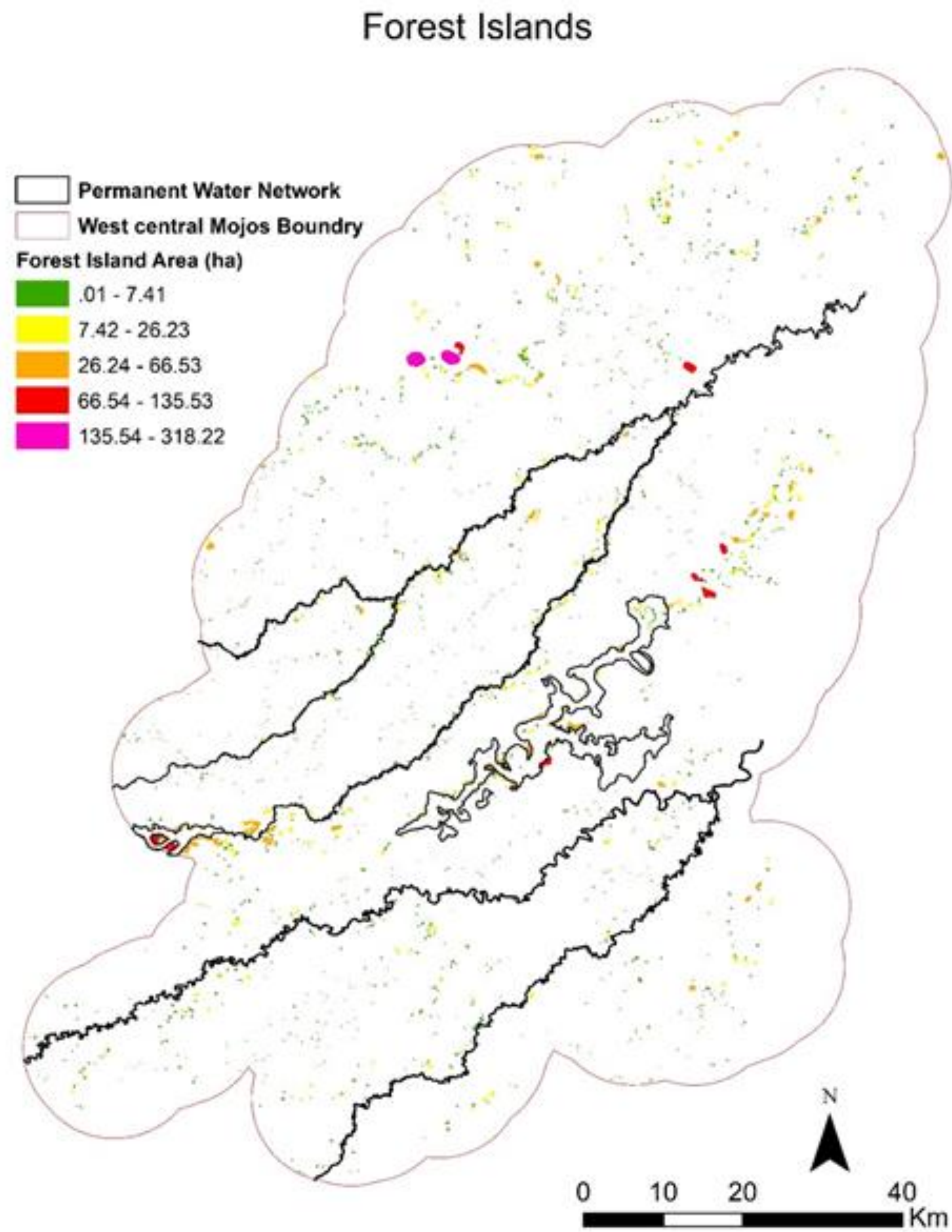


Figure 63: The distribution of forest islands throughout west central Mojos

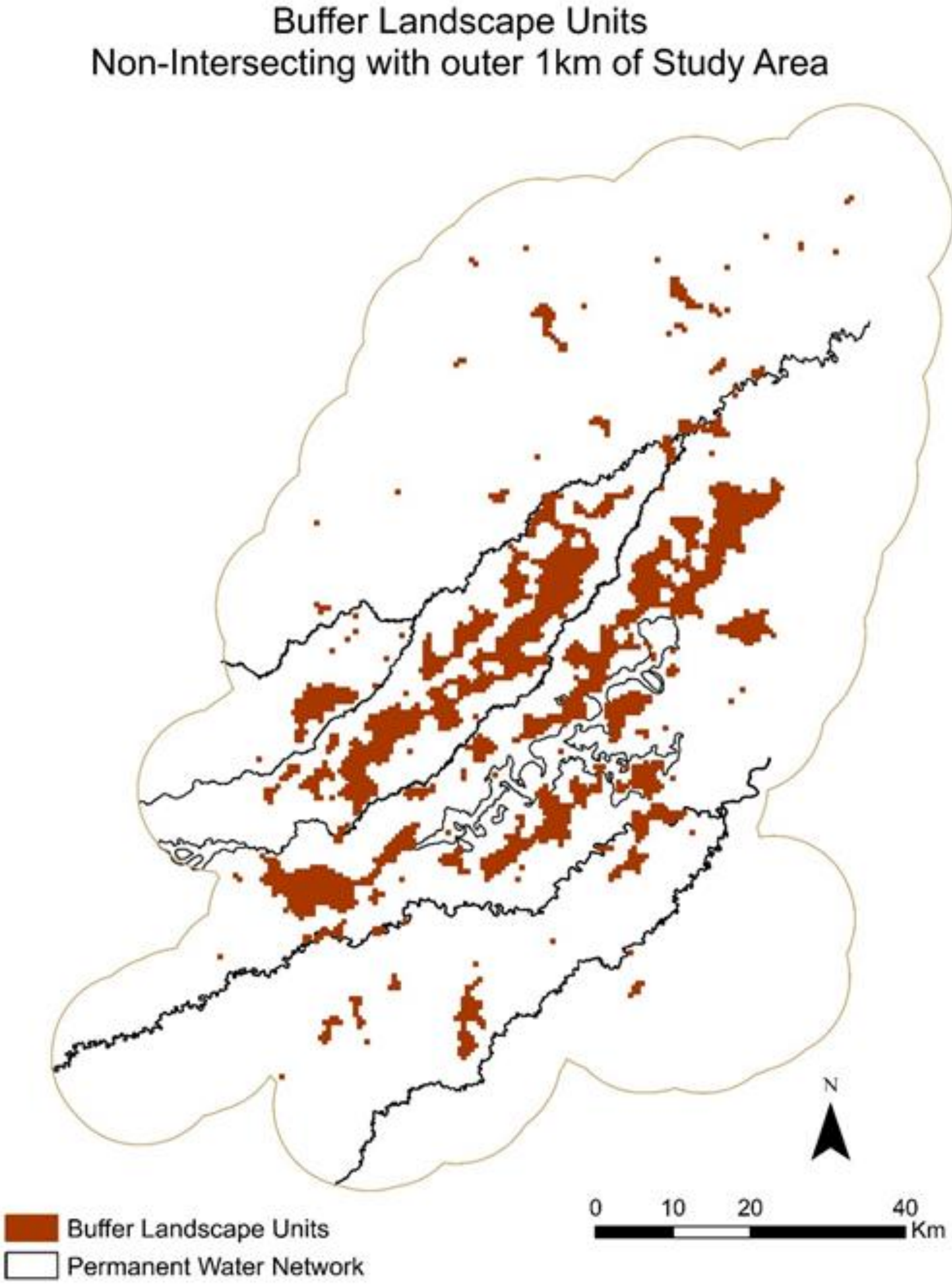


Figure 64: Not all Buffer Landscape Units intersect with the outer border of the study area. Removing buffers that intersect with the study area polygon leaves behind a section of Buffers near the center of the study area.

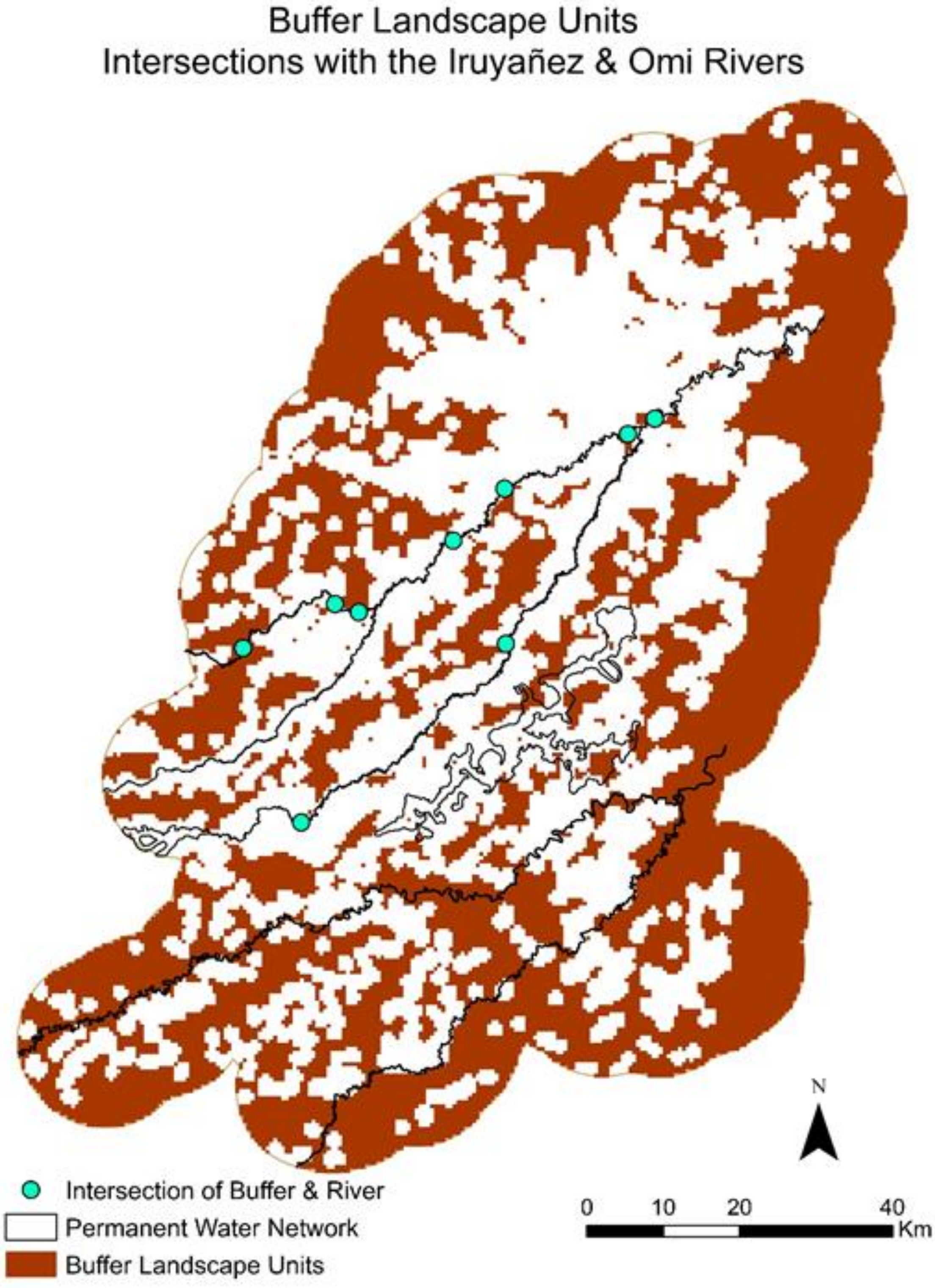


Figure 65: Buffer landscape units intersect with the Iruyañez and Omi rivers in only a few select locations. Intersections along the Yacuma and Rapulo rivers are much more significant and not reduced to small points.

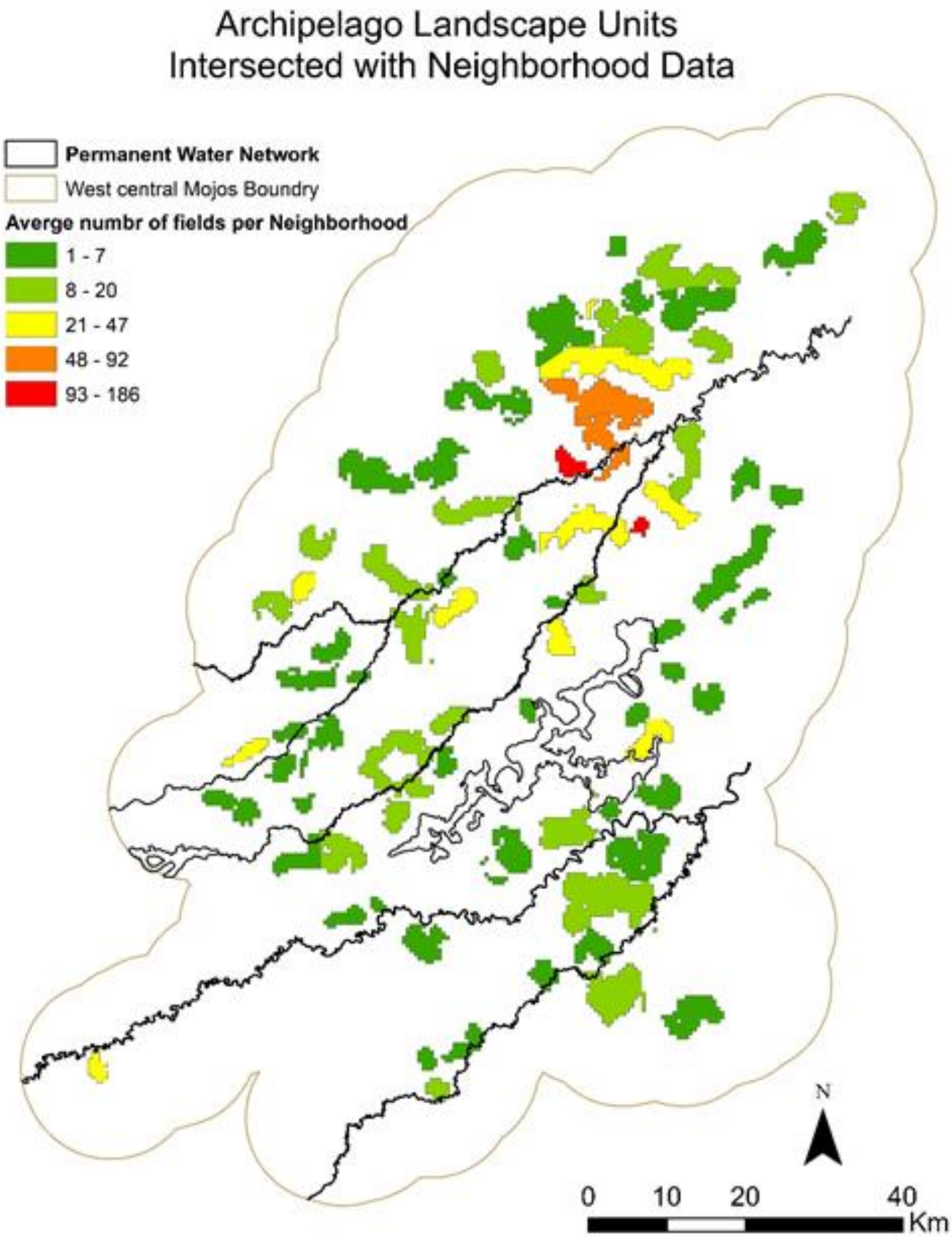


Figure 66: Archipelago Landscape Units are represented by the average size of a Neighborhood within each unit. Neighborhood size is measured by the average number of platforms per Neighborhood. Archipelagos near the confluence of the Iruyañez and Omi rivers have much larger Neighborhoods than other parts of the study area.

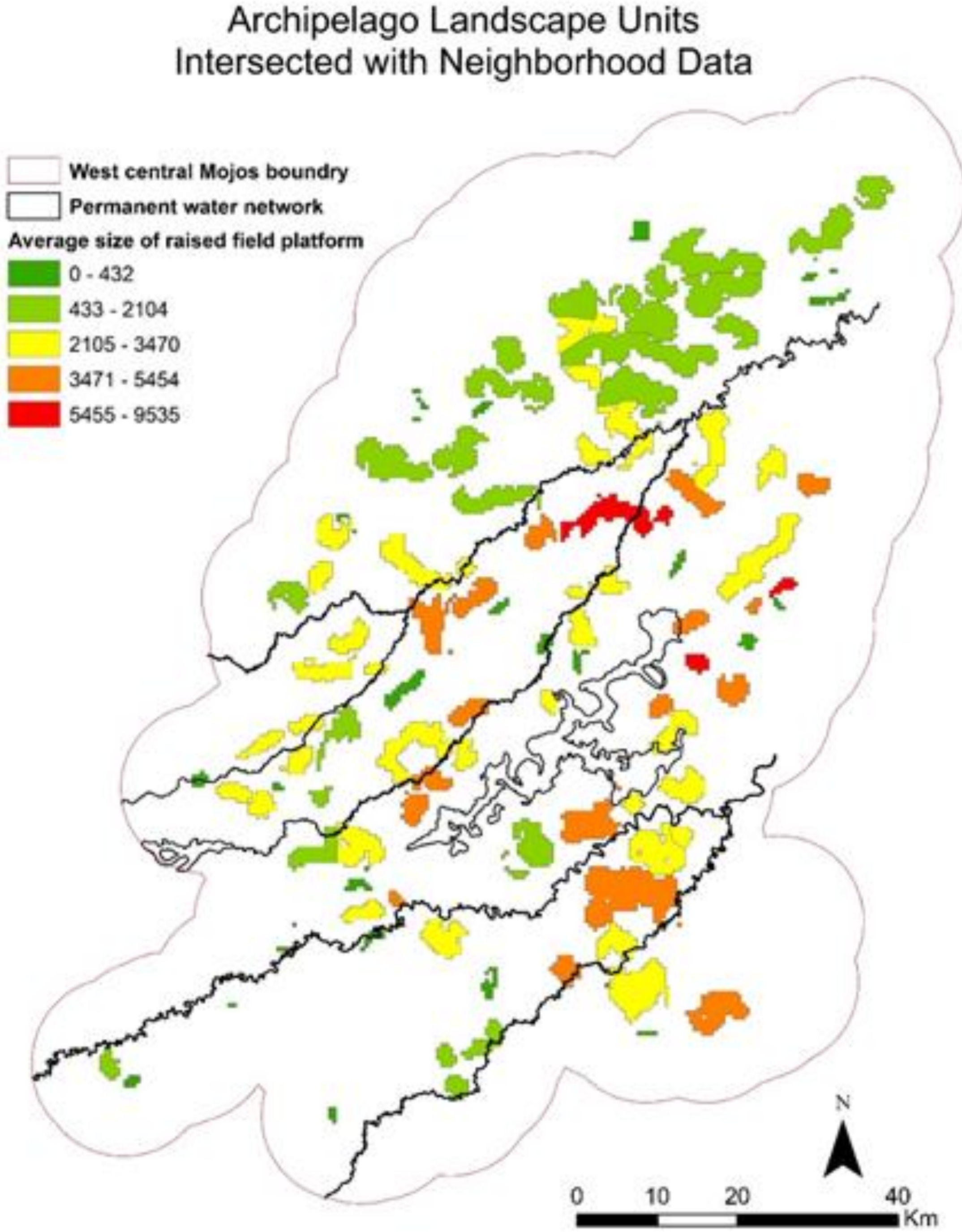


Figure 67: Archipelago Landscape Units are represented by the average size of a Neighborhood within each unit. Neighborhood size is measured by the average size of a platform within the Neighborhood. This map indicates that north of the Iruyañez river, platforms are smaller in size on average than those further to the south.

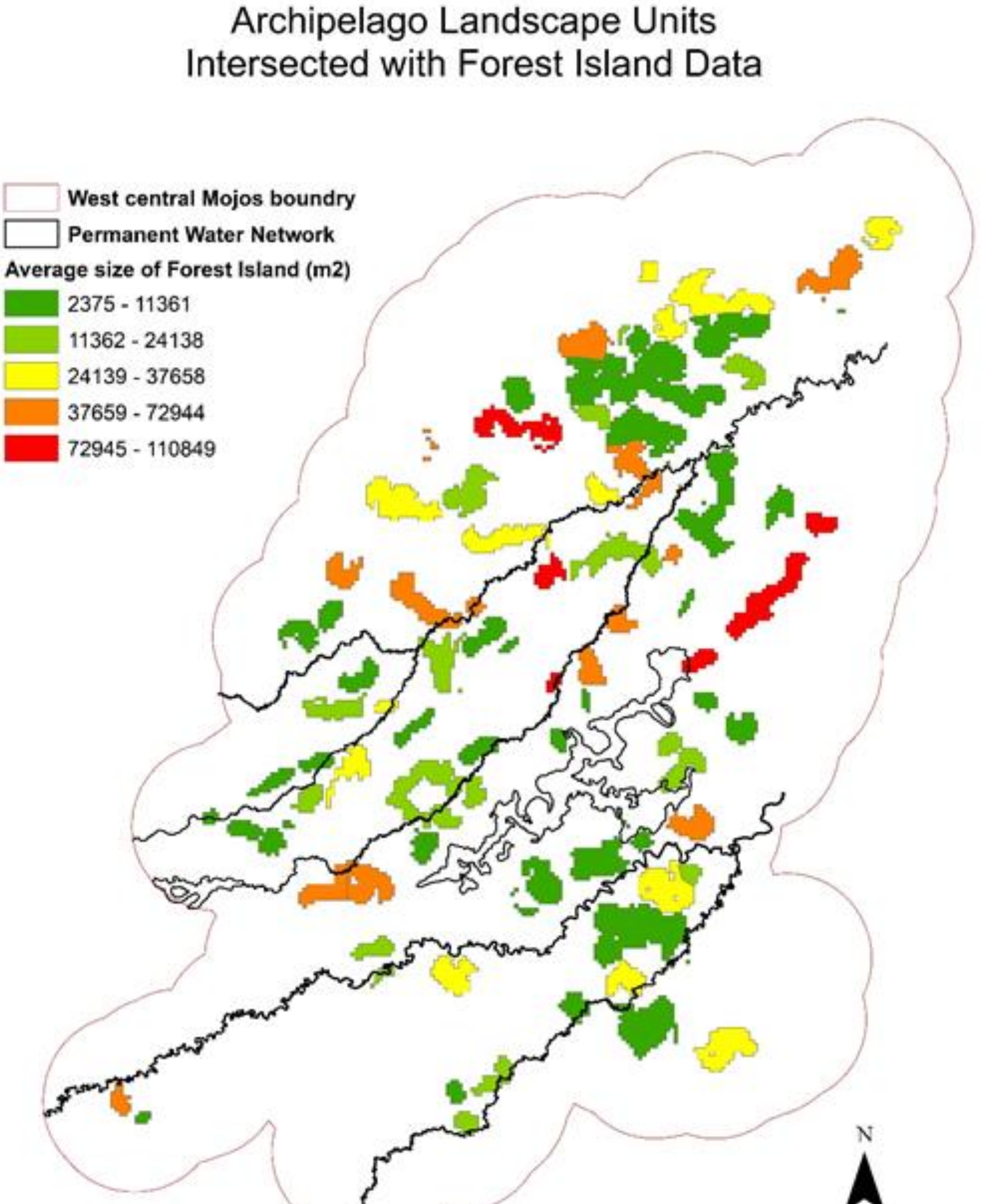


Figure 68: Archipelago Landscape Units are represented by the average size of the forest islands within each unit.

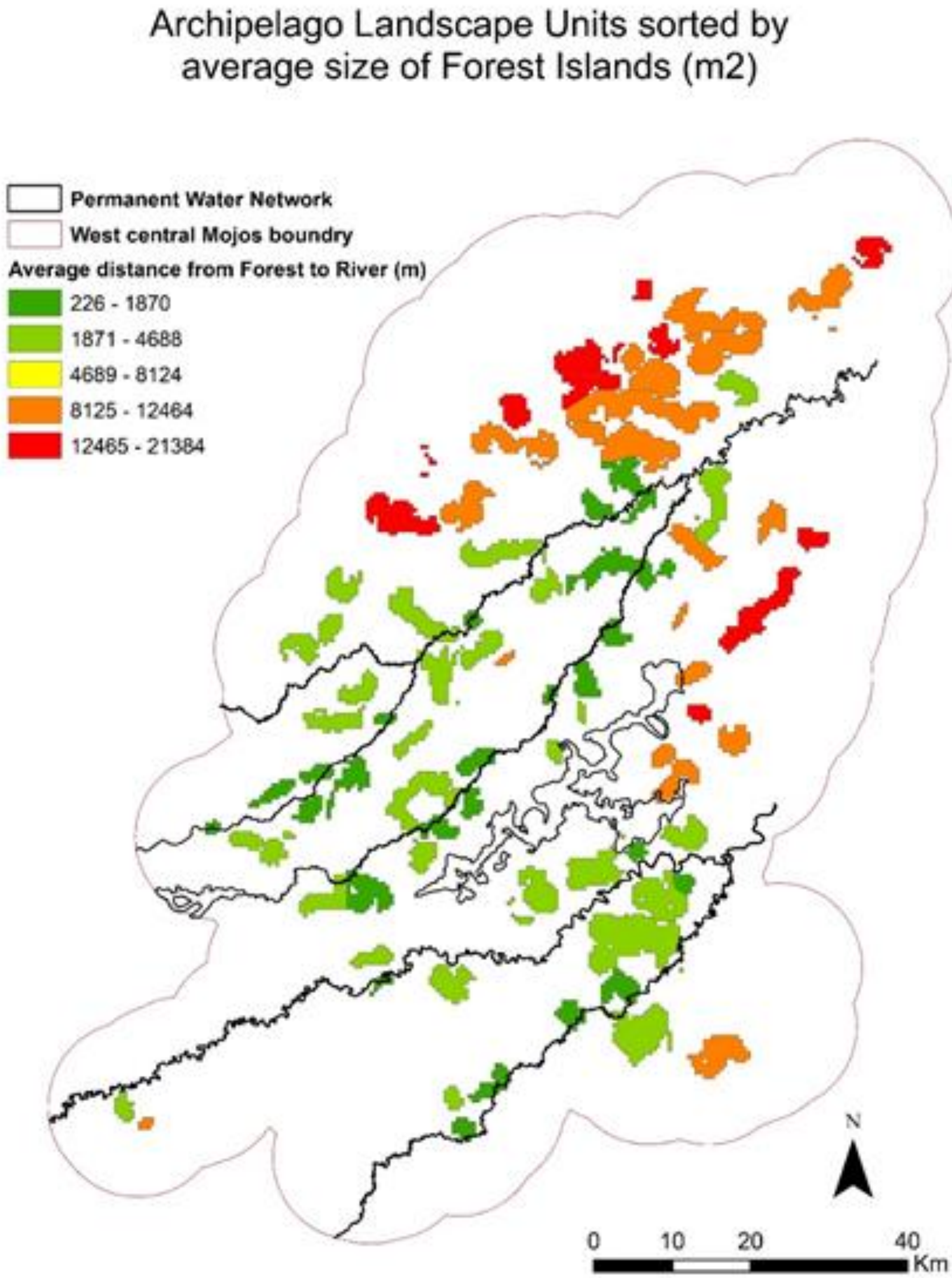


Figure 69: Archipelago Landscape Units are organized by the average distance from the forest islands within the units to the nearest permanent river. This map indicates which archipelago units are located the farthest from one of the 4 permanent rivers in the study.

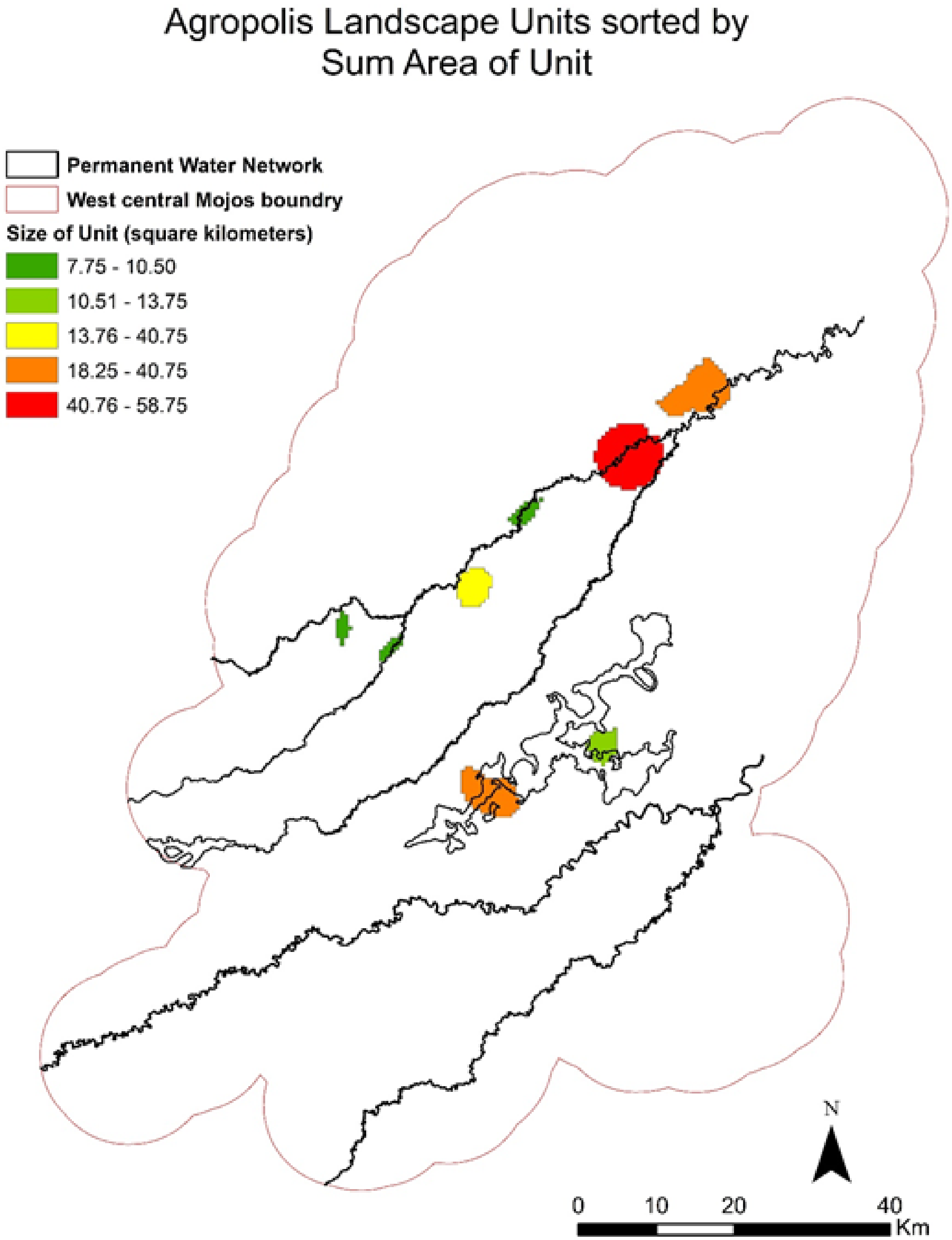


Figure 70: Agropolis Landscape Units organized by the size of each individual unit.

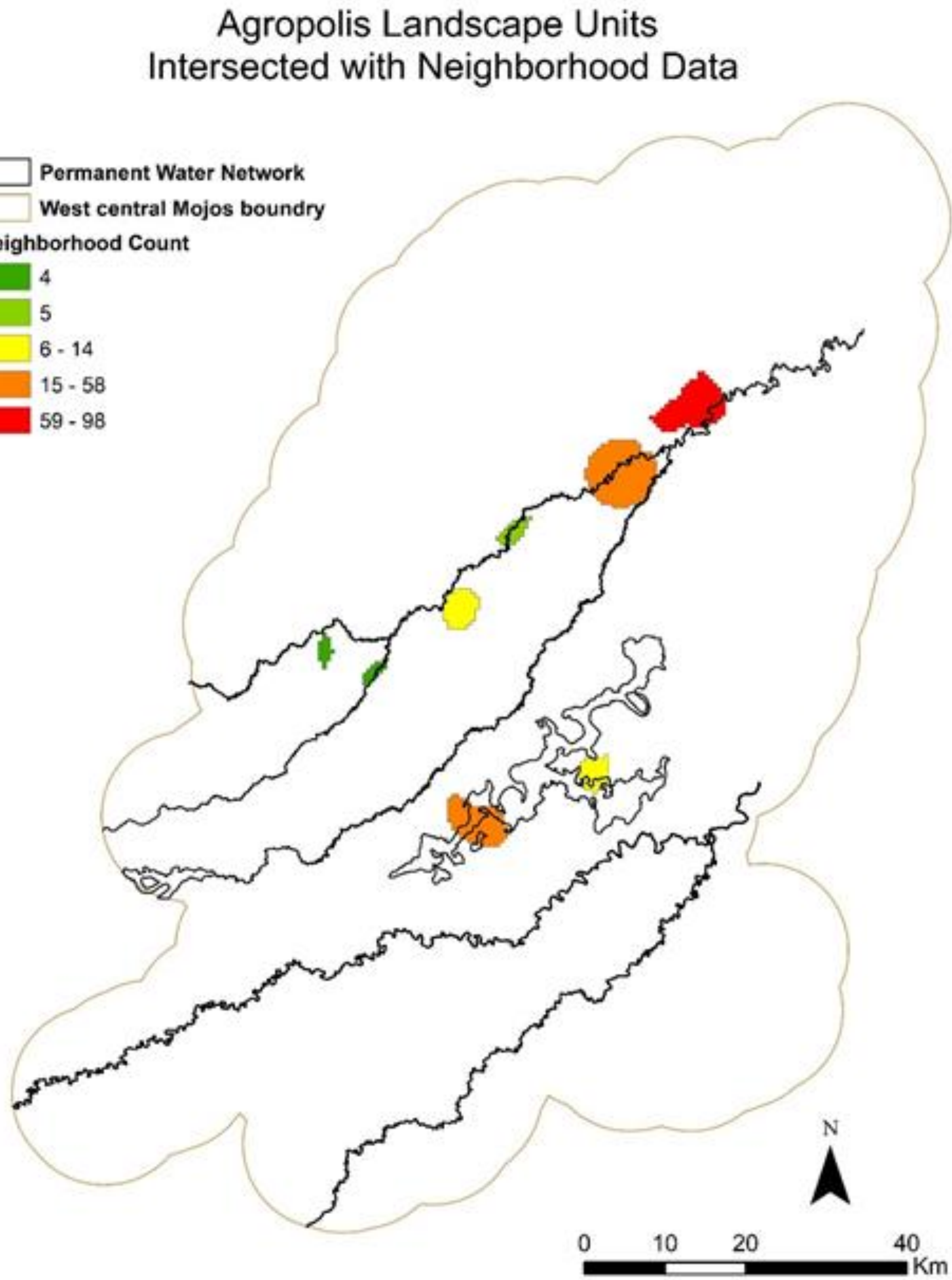


Figure 71: Agropolis Landscape Units organized by the number of Neighborhoods located within each unit.

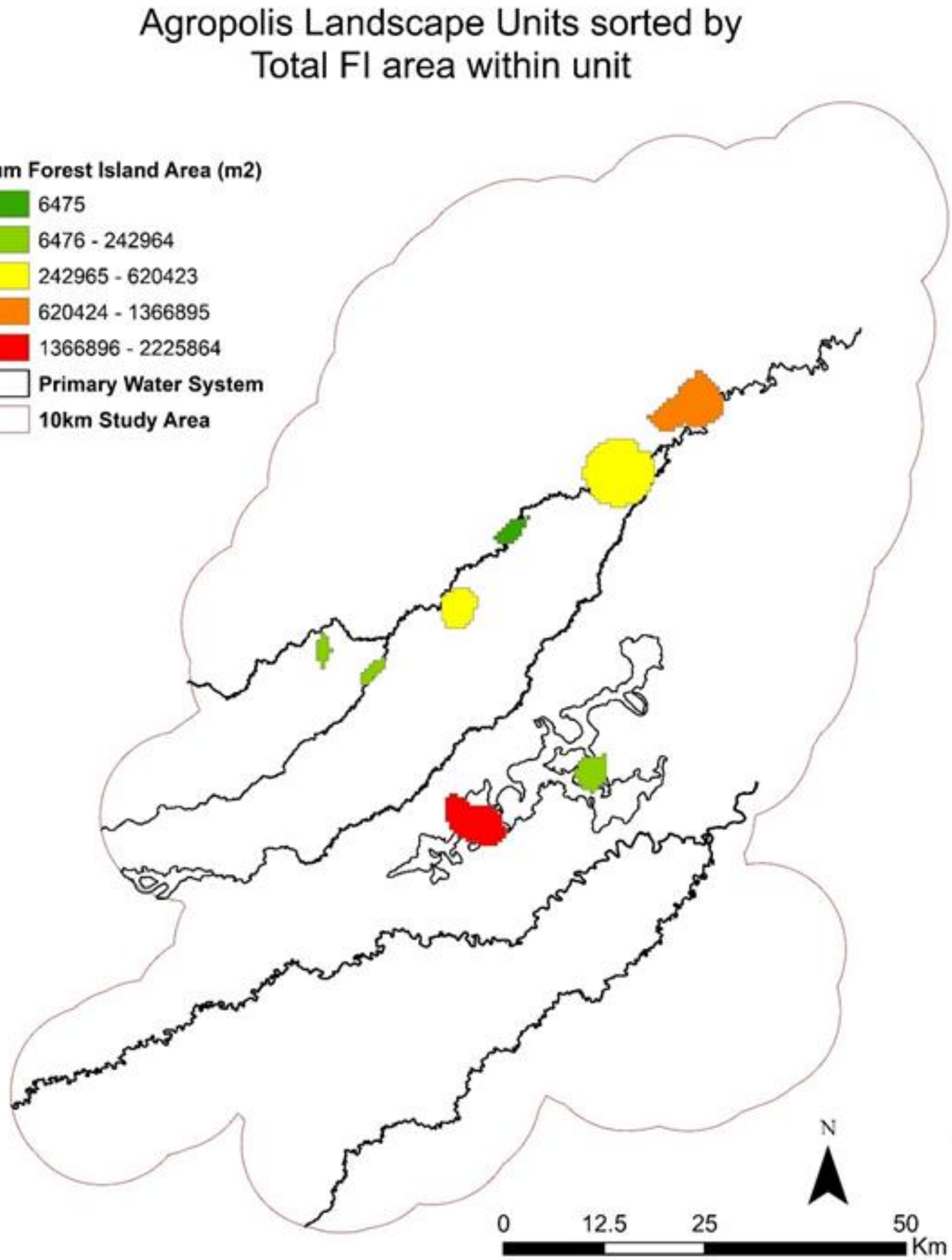


Figure 72: Agropolis Landscape Units organized by the total amount of forest island surface area within each individual unit.

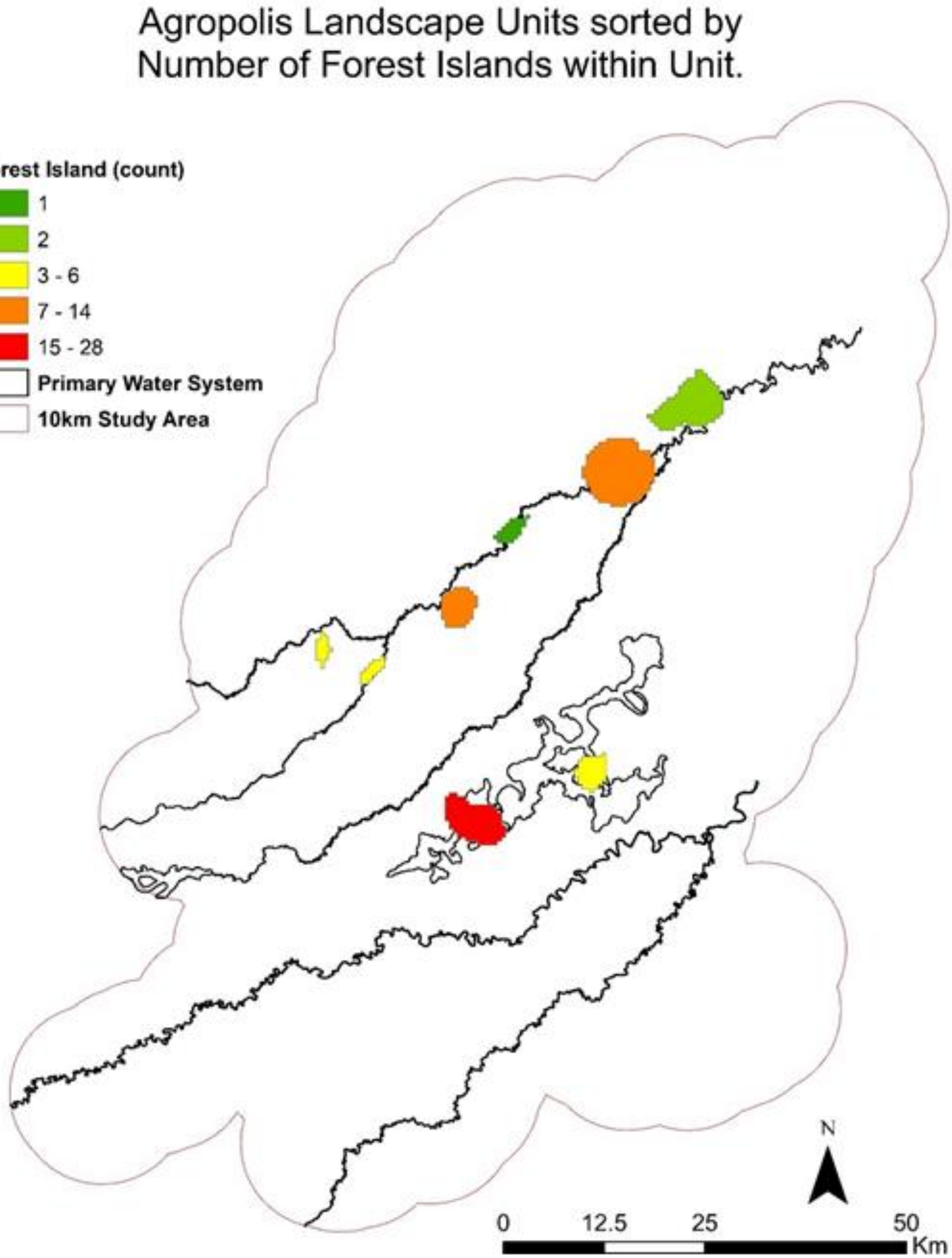


Figure 73: Agropolis Landscape Units organized by the total number of forest islands within each unit.

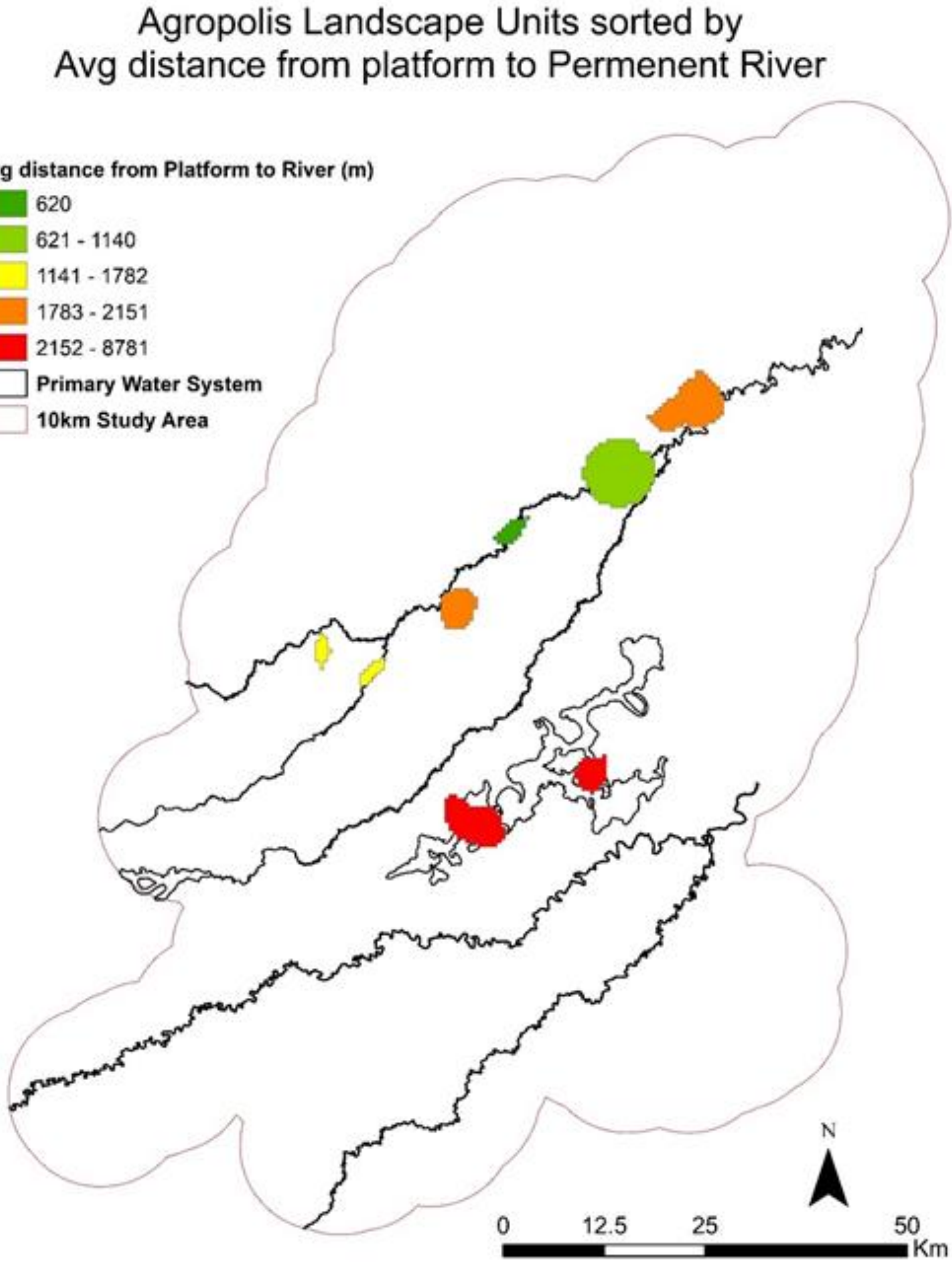


Figure 74: Agropolis Landscape Units organized by the average distance from raised fields within each unit to the nearest permanent flowing river.

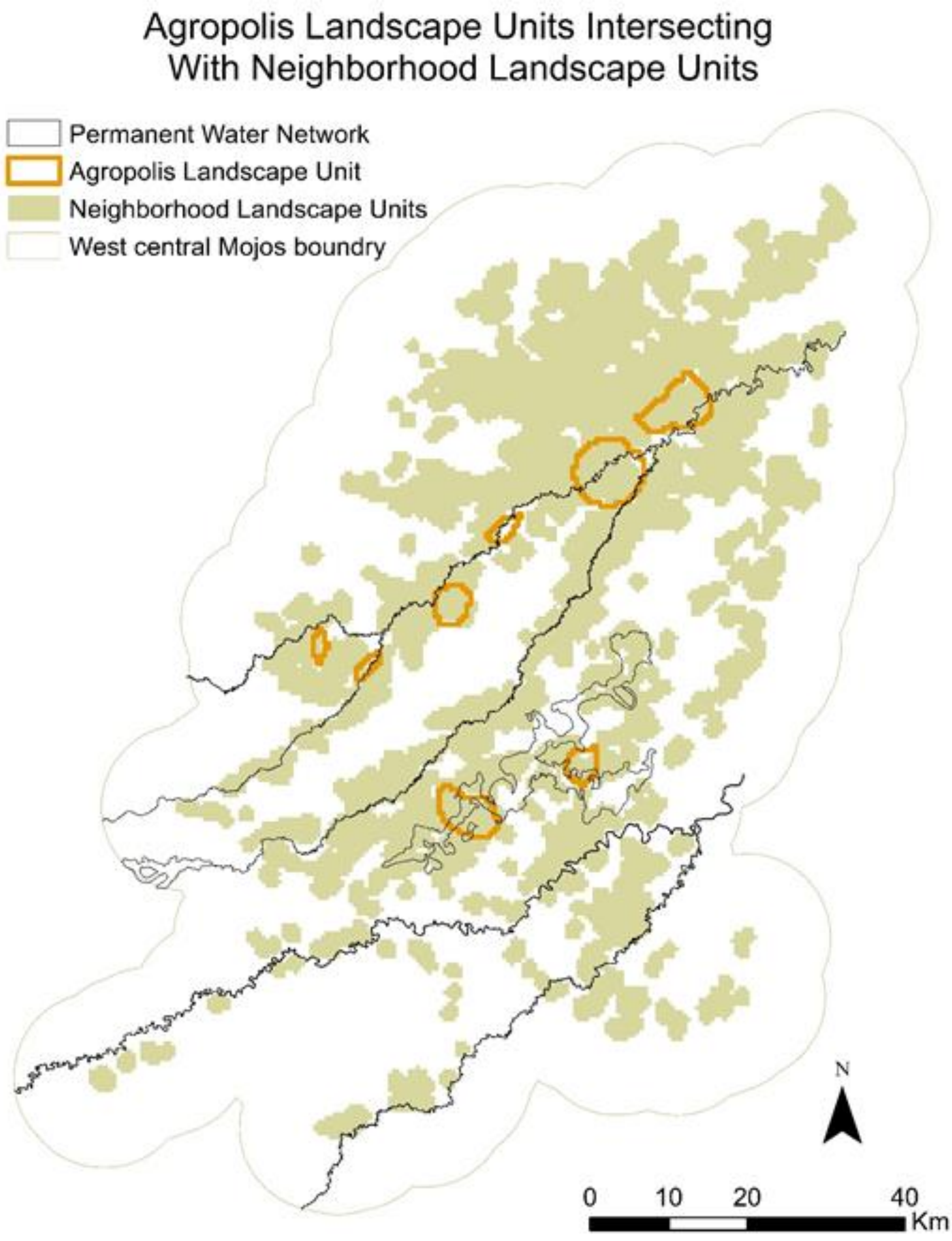


Figure 75: Agropolis Landscape Units intersected with Neighborhood Landscape Units for comparison.

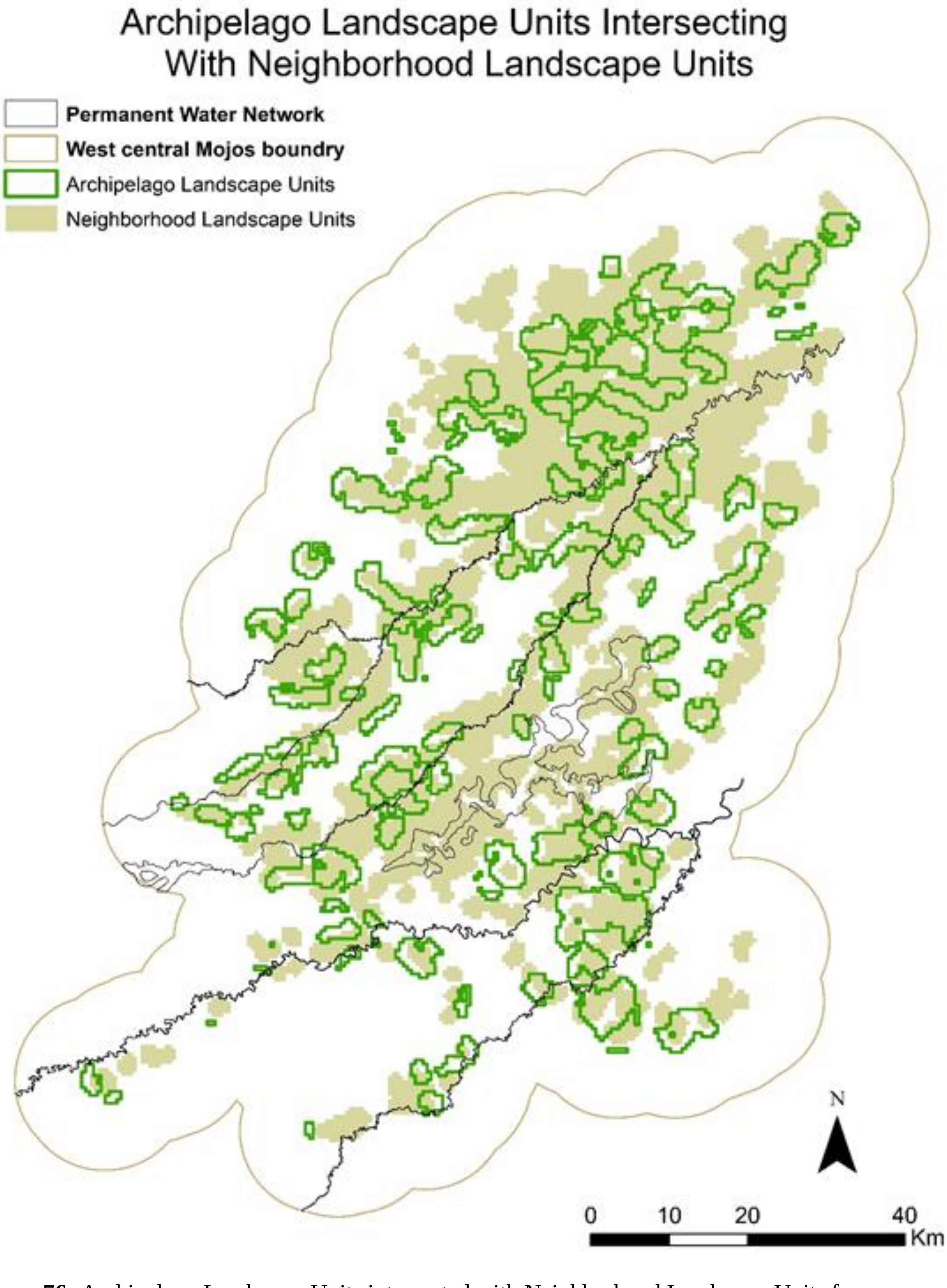


Figure 76: Archipelago Landscape Units intersected with Neighborhood Landscape Units for comparison.

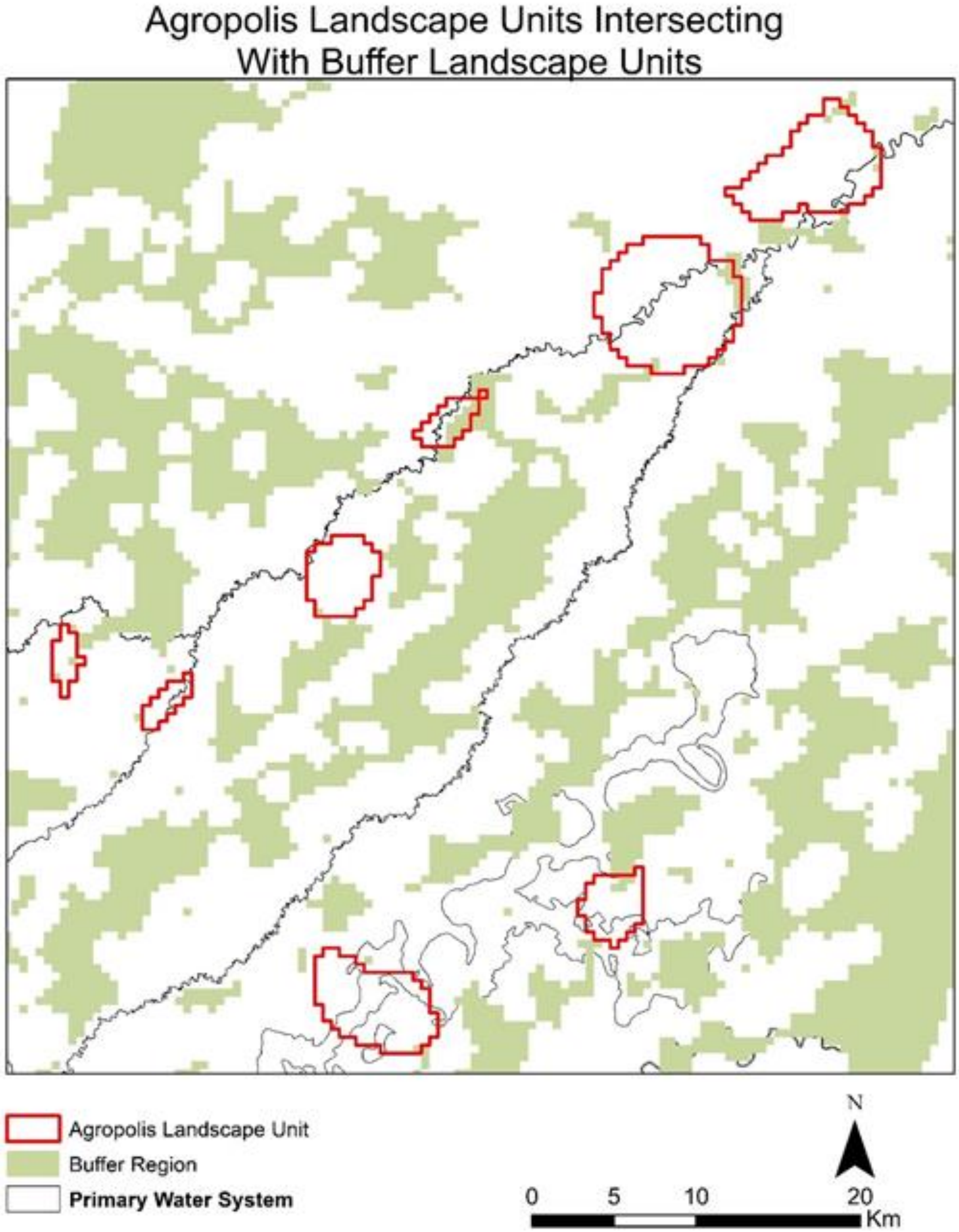


Figure 77: Agropolis Landscape Units intersected with Buffer Landscape Units for comparison.

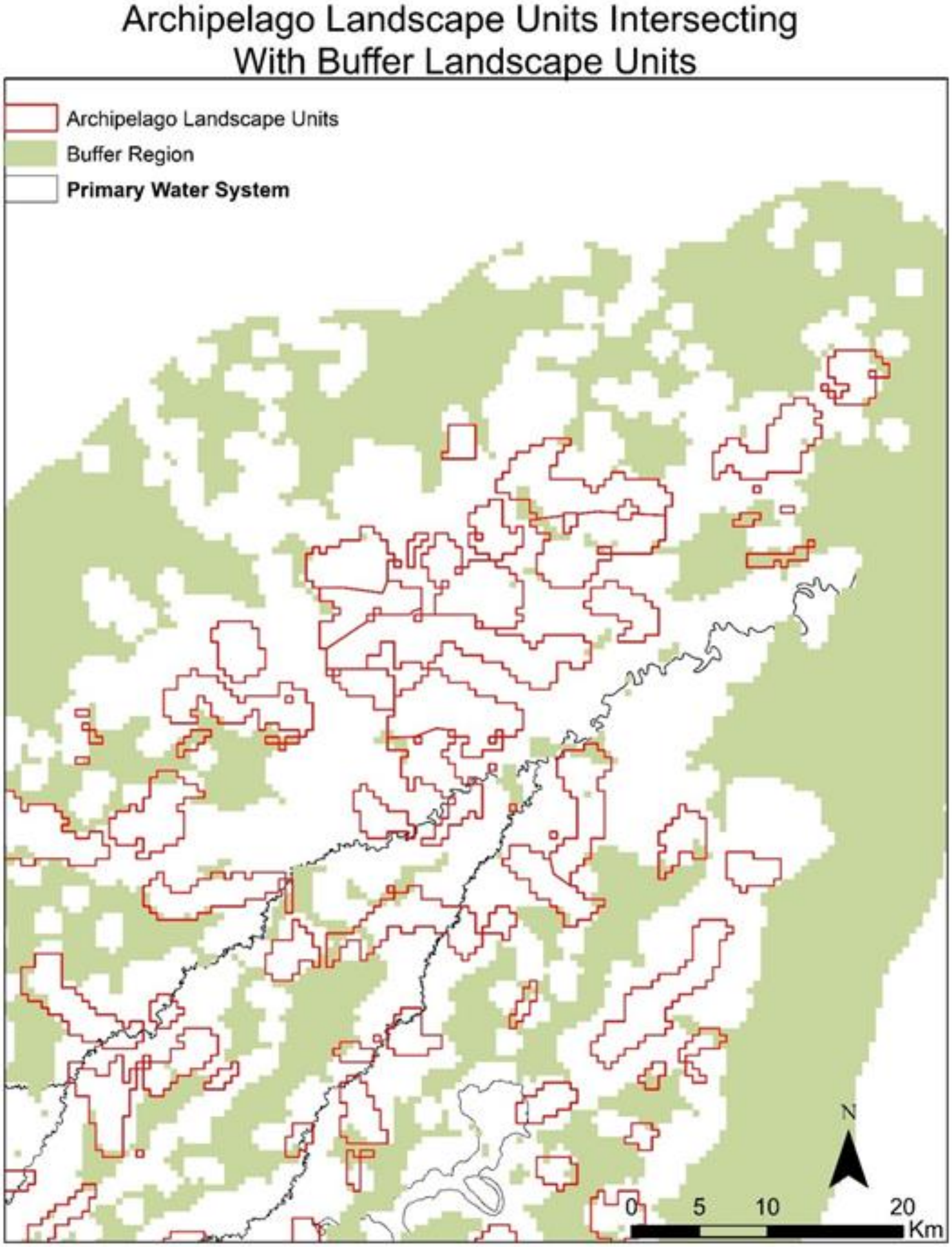


Figure 78: Archipelago Landscape Units intersected with Neighborhood Landscape Units.

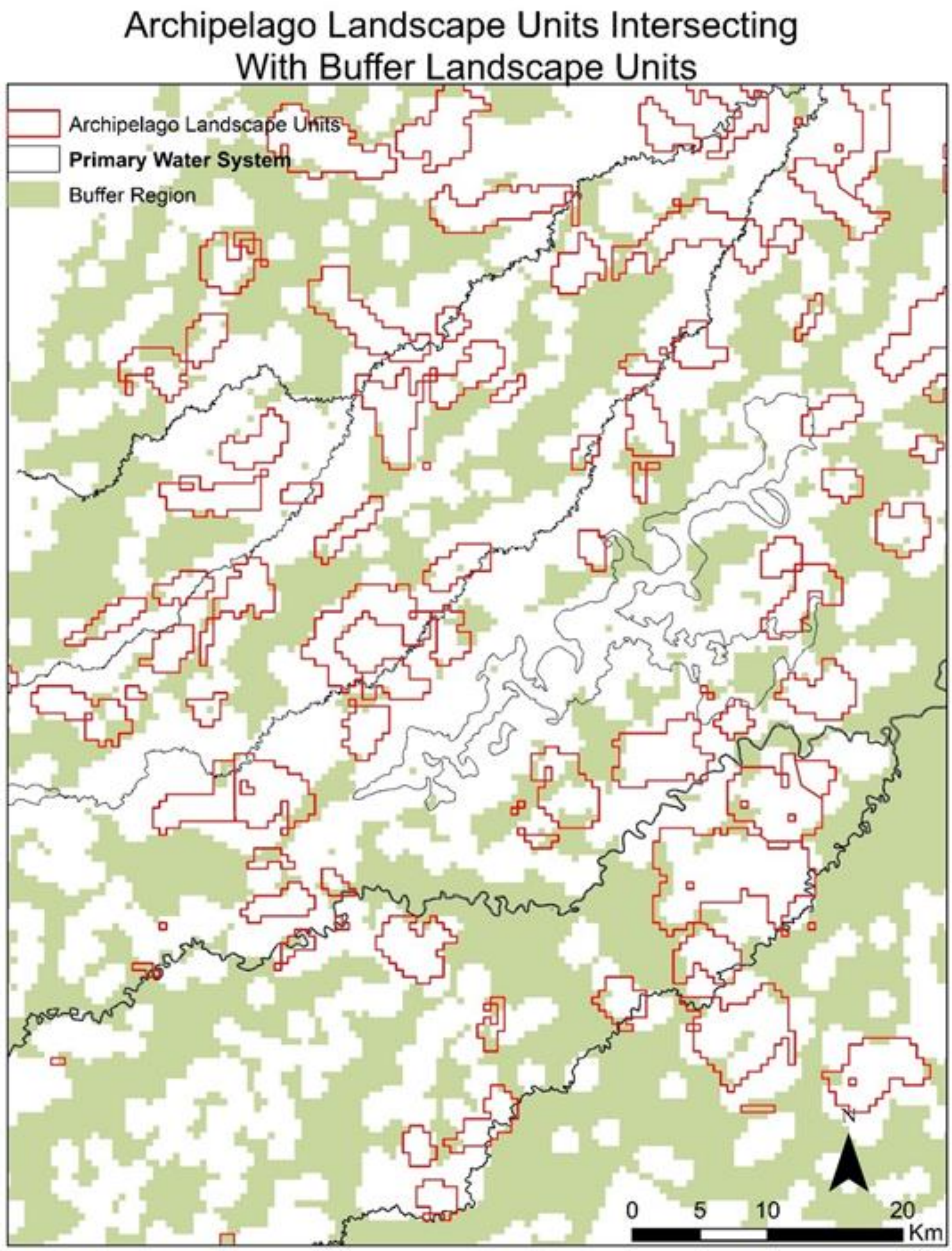


Figure 79: Archipelago Landscape Units intersected with Neighborhood Landscape Units.

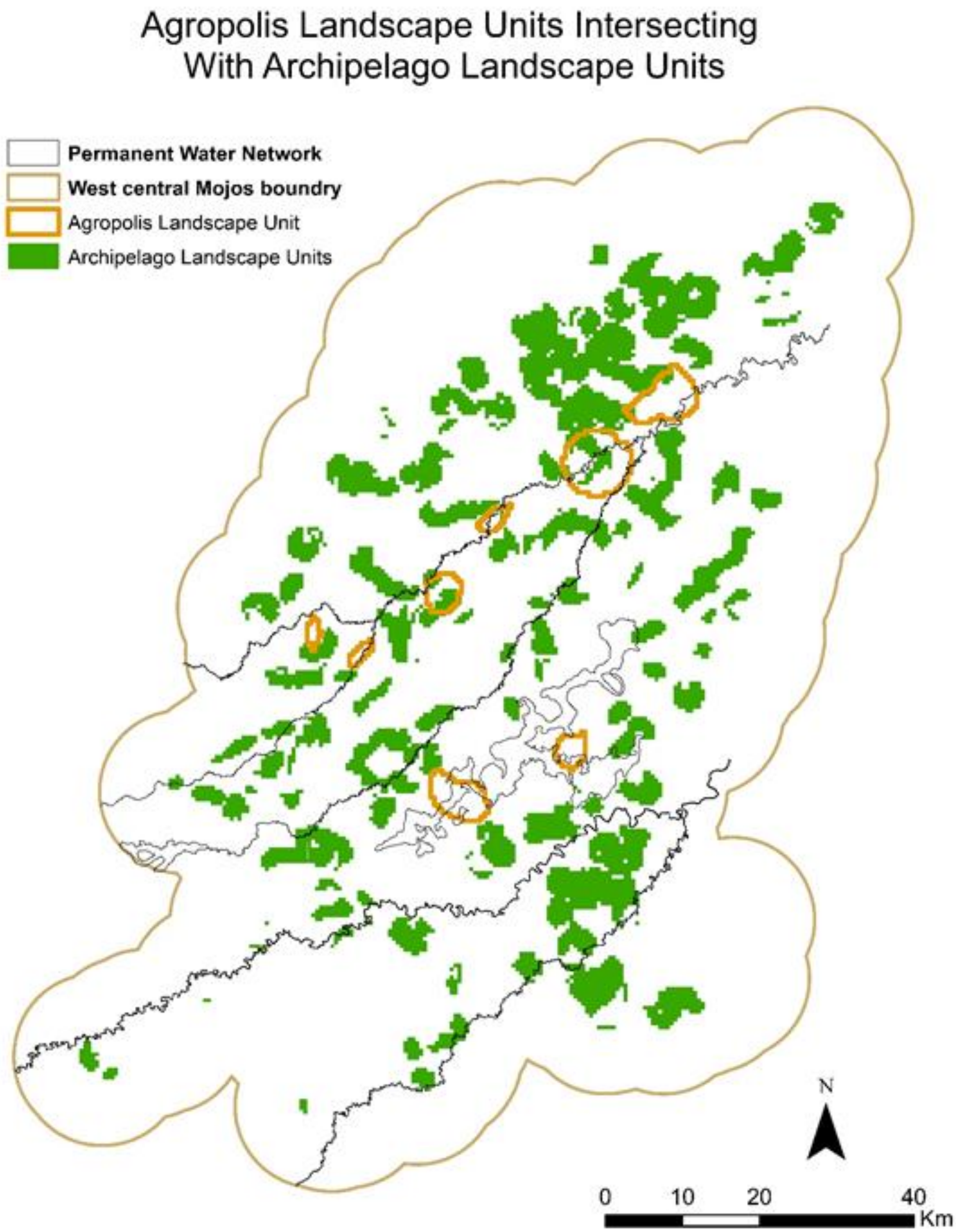


Figure 80: Agropolis Landscape Units intersected with Archipelago Landscape Units for comparison.

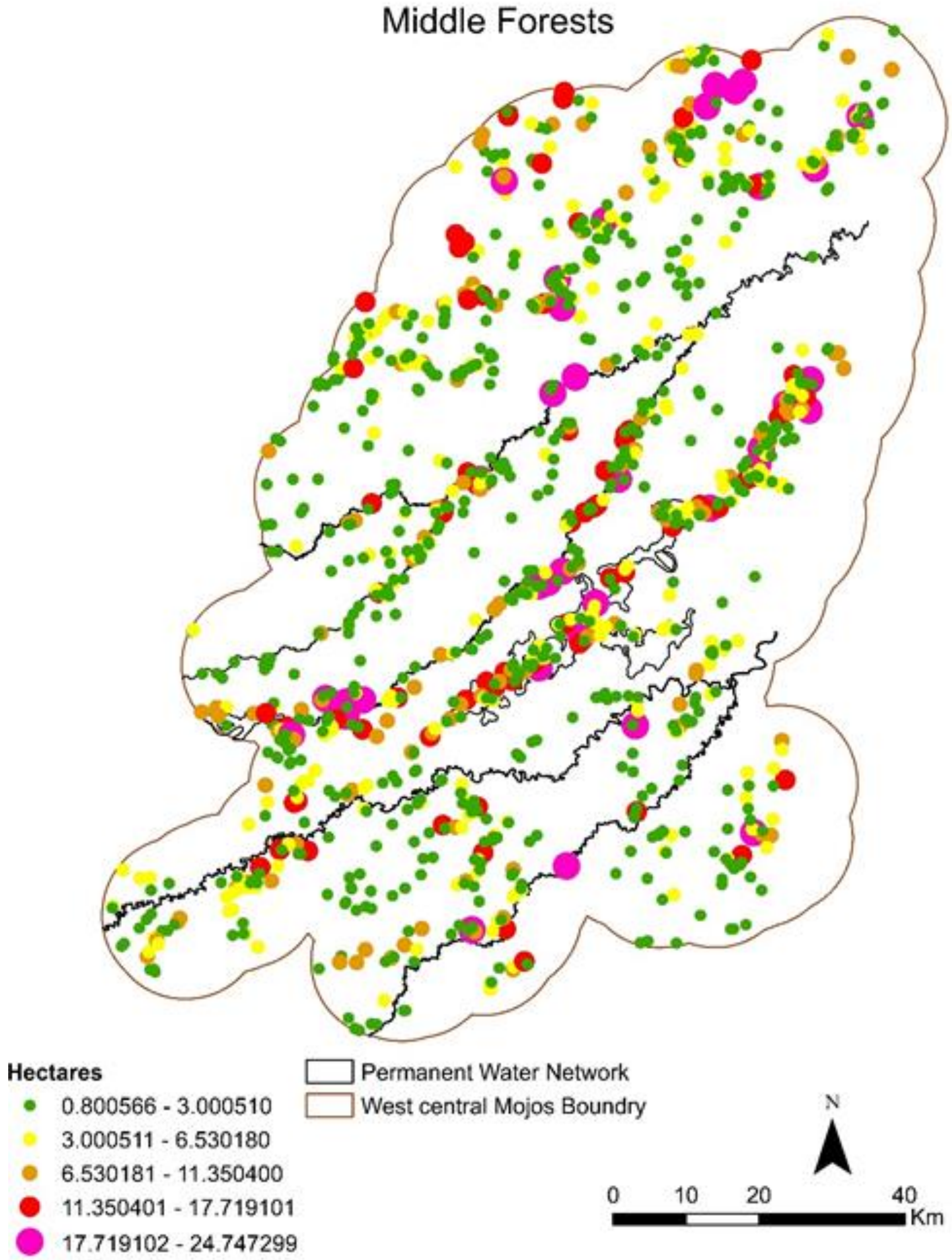


Figure 81: This map contains a point for each forest island that was too large to be suitable for an Archipelago Landscape Unit and also too small to be considered suitable for an Agropolis Landscape Unit. Medium sized forest islands are consistently clustered along the major rivers in the north and along the Quinato wetland in the south.

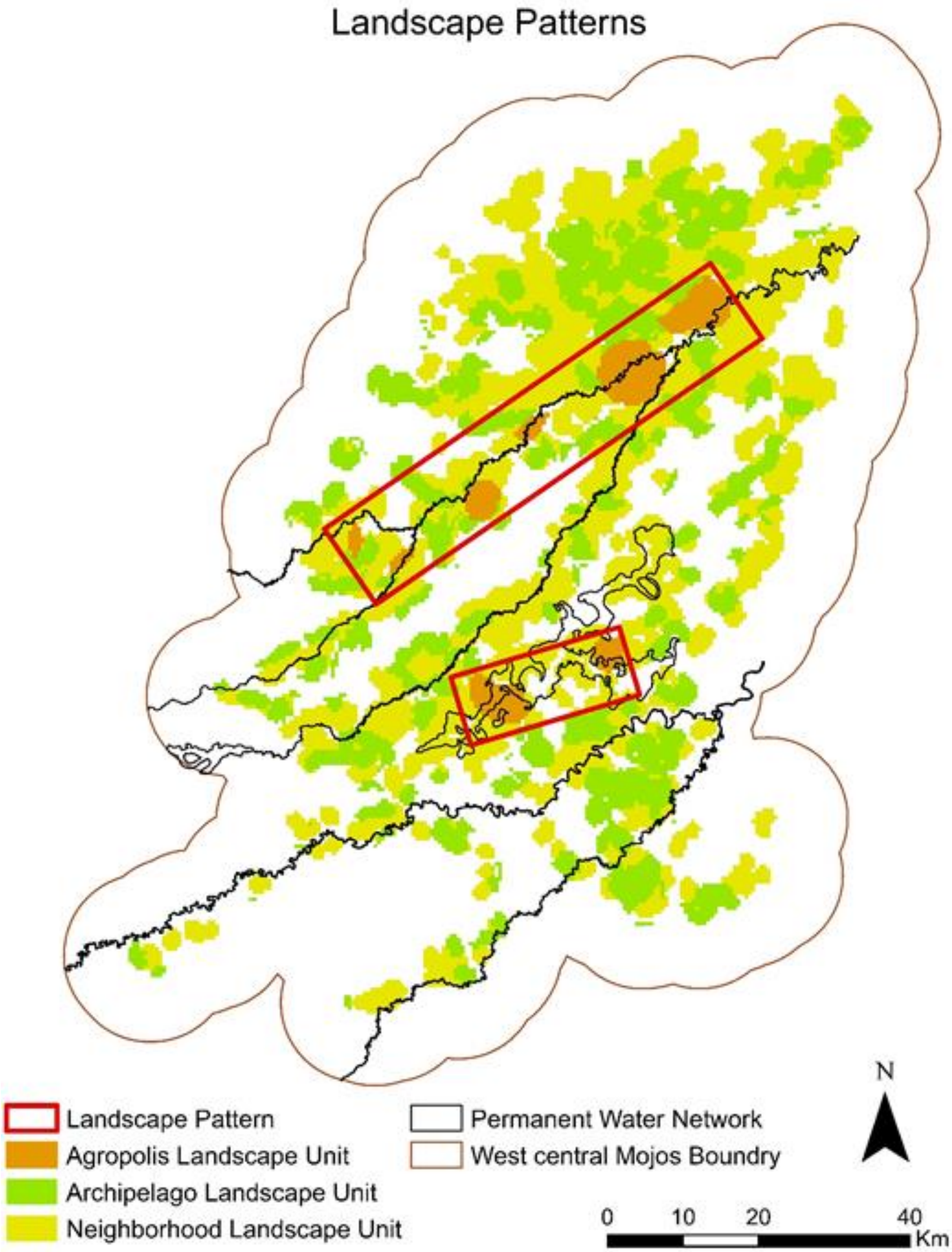


Figure 82: The organization of Landscape Units demonstrates two distinct patterns of organization. In the norther part of the study area, Agropolis units are organized along the permanent flowing river. In the south the Agropolis Landscape Units are organized along the Quinato wetland at a great distance from the permanent flowing rivers.

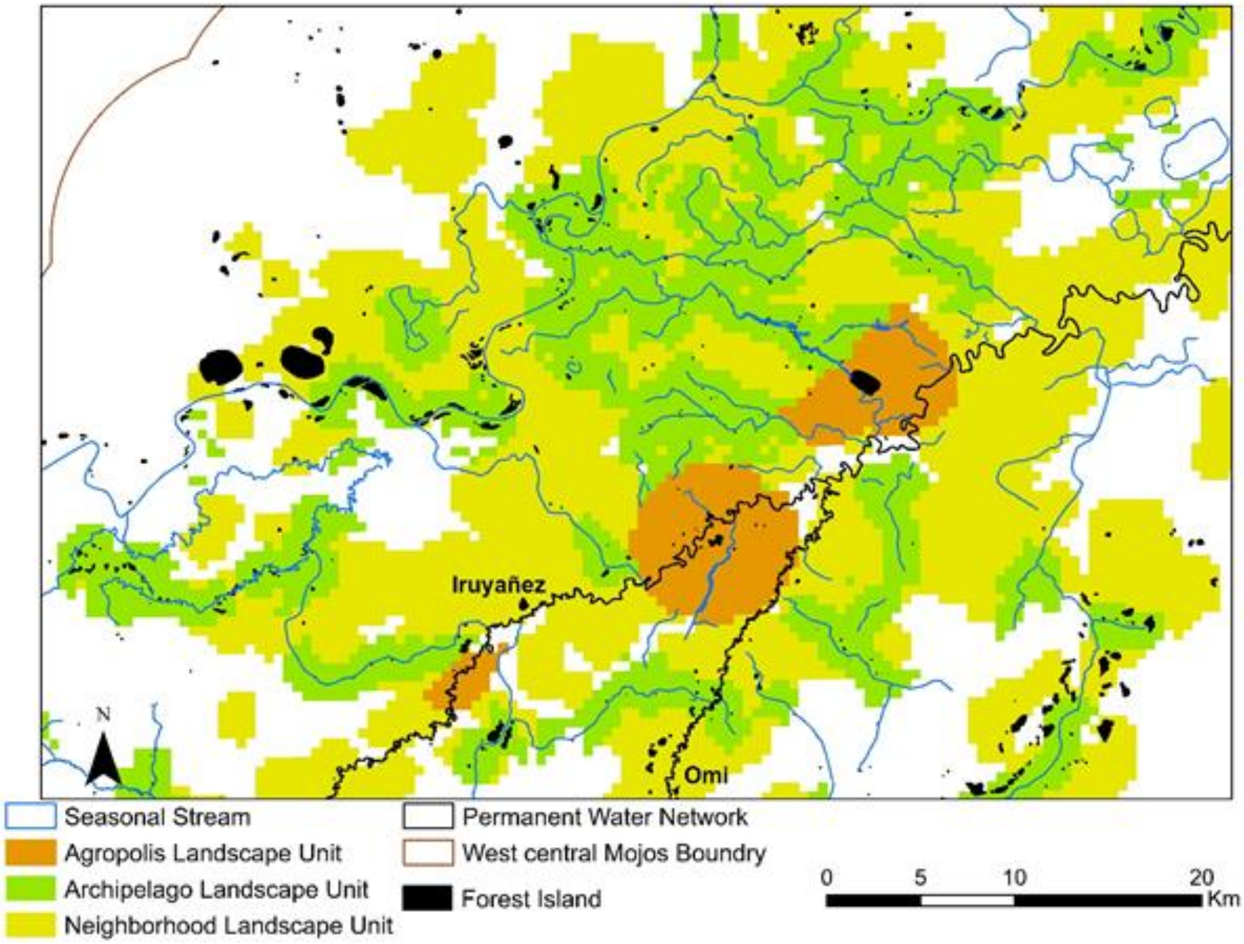


Figure 83: In the northern portion of the study area, Agropolis Landscape Units are spaced out along the Iruyañez river.

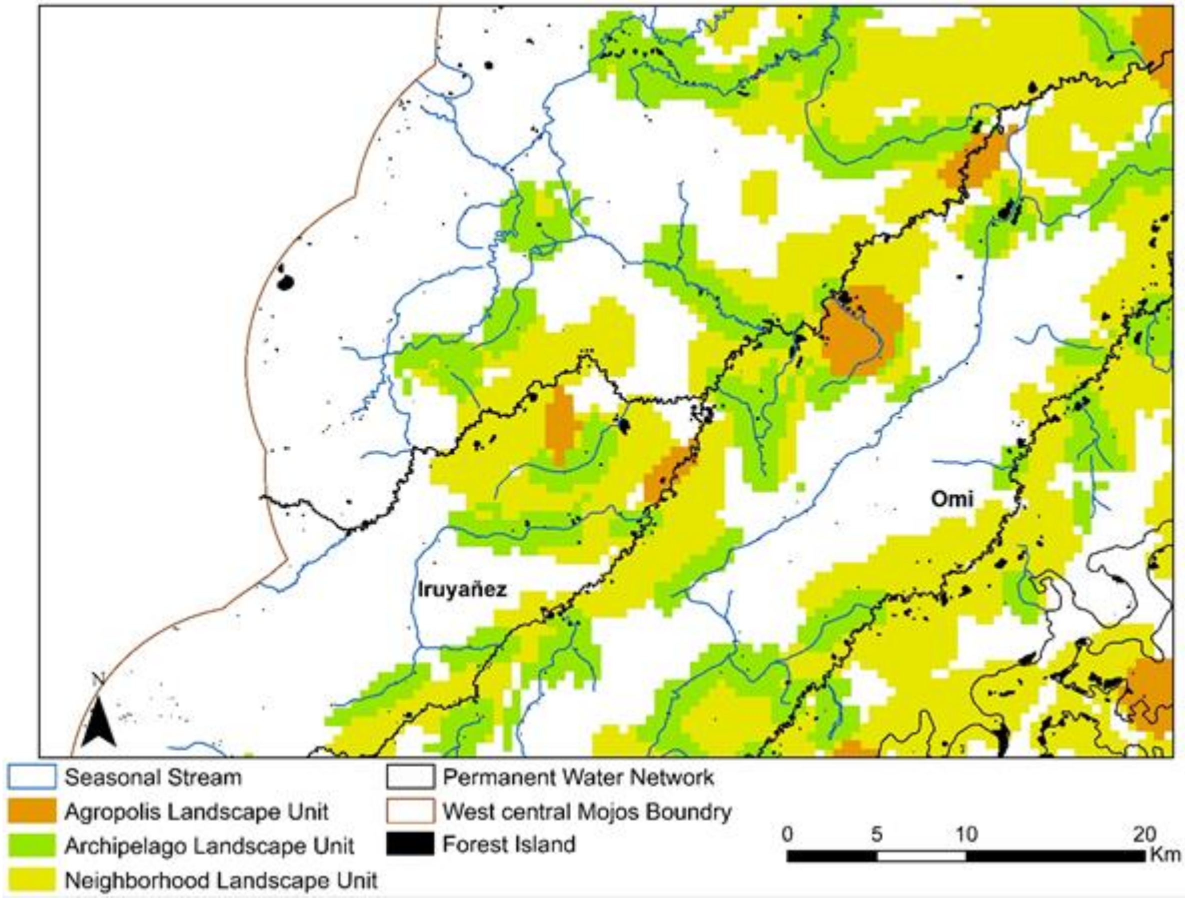


Figure 84: In the northern portion of the study area, Agropolis Landscape Units are spaced out along the Iruyañez river.

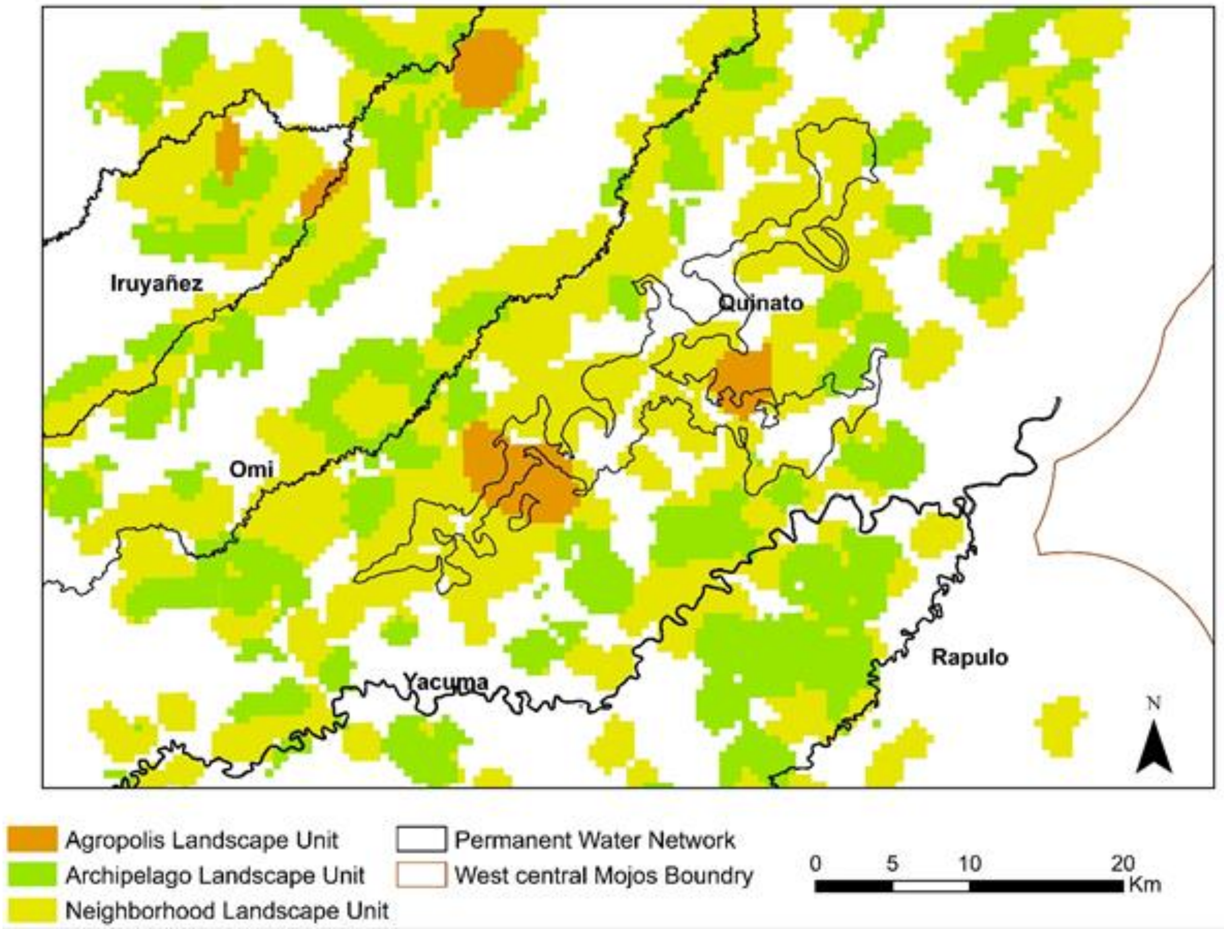


Figure 85: In the southern portion of the study area, Agropolis Landscape Units are spaced out along the Quinato wetland. These Landscape Units are organized between the rivers rather than along their banks.

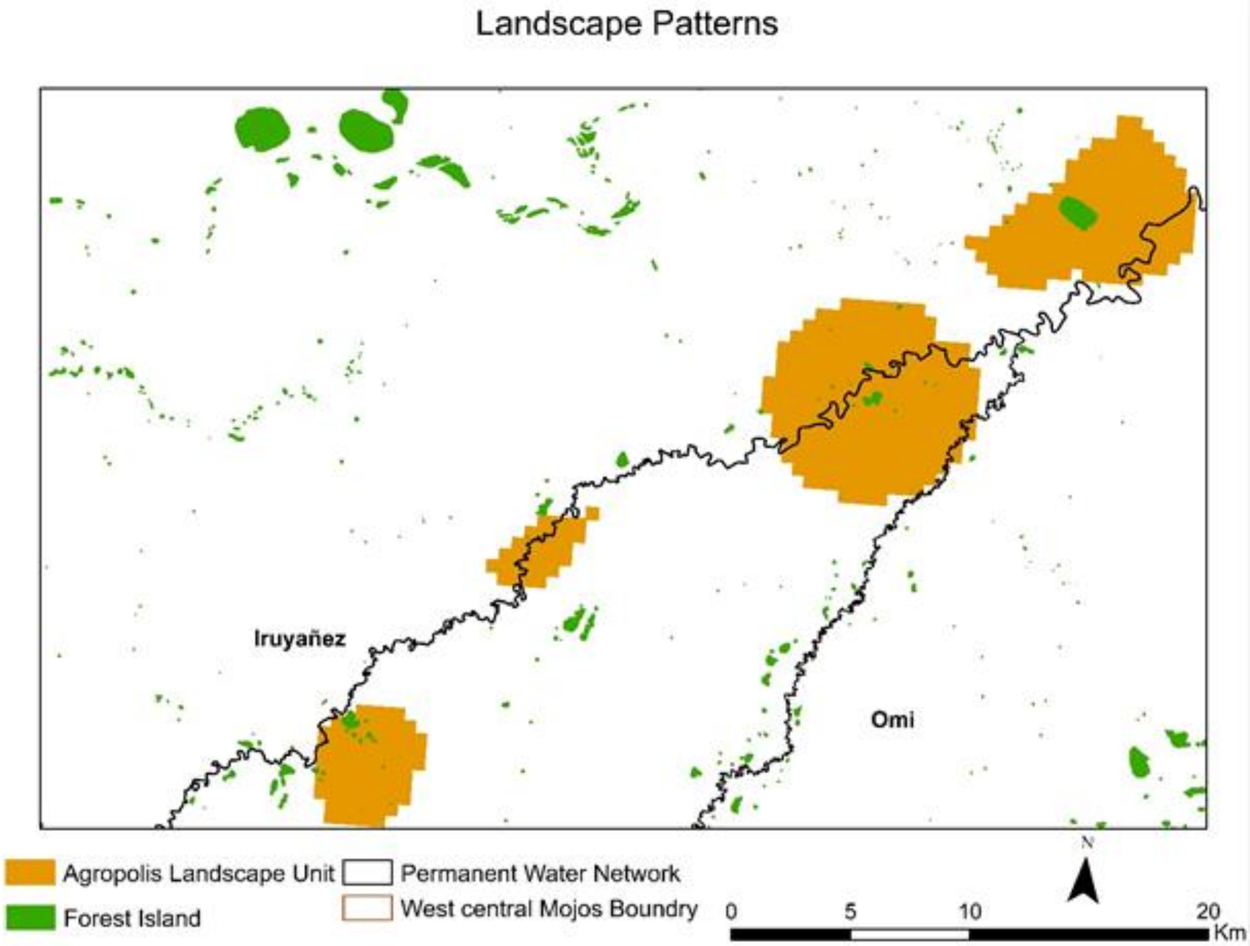


Figure 86: Large forest islands are spaced out along the Iruyañez river with an average of 10,750km separating them.

Landscape Patterns

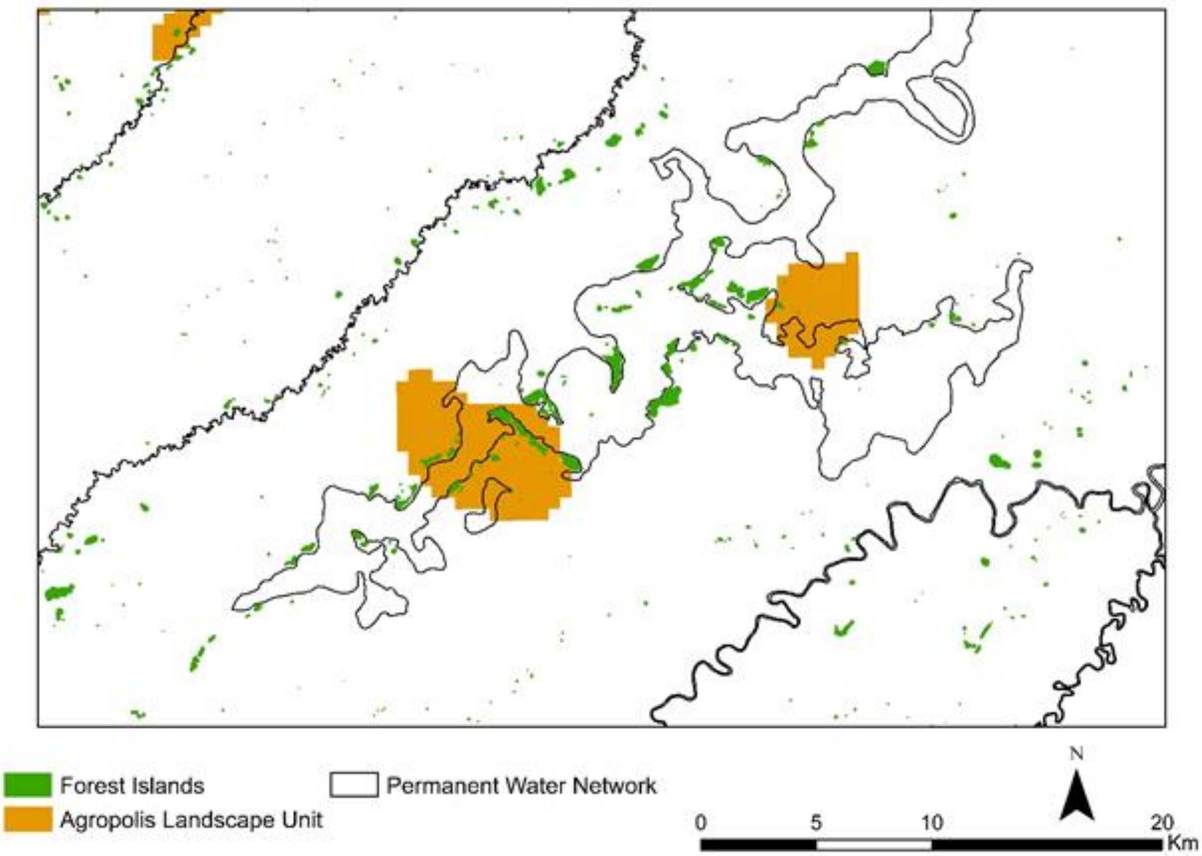


Figure 87: Large forest islands are tightly clustered along the Quinato wetland with less than a kilometer separating most islands.

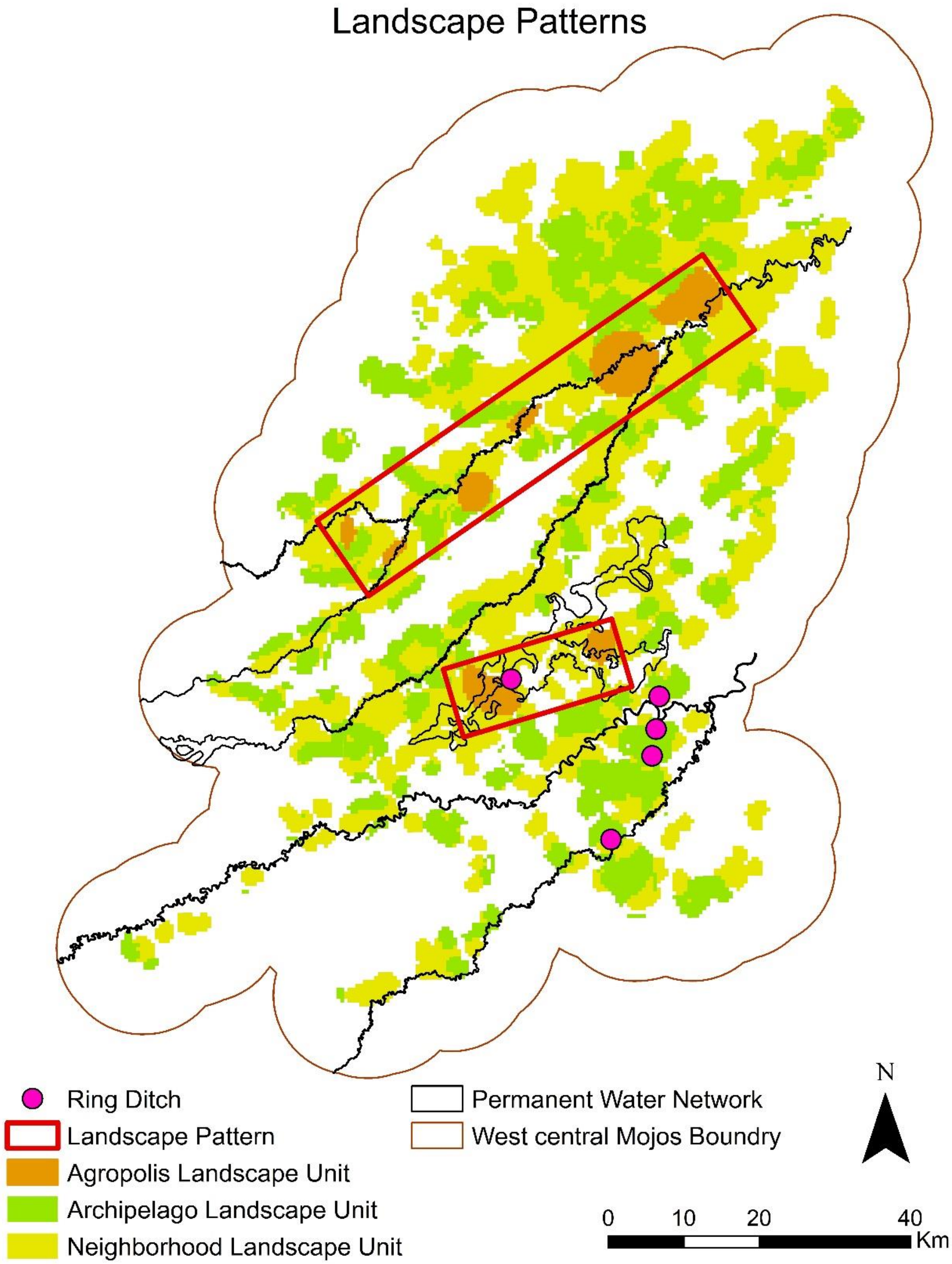


Figure 88: The distribution of ring ditch earthworks in west central Mojos coincides with the southern region of the study area. No ring ditches have been identified north of the Quinato wetland. Other ring ditches have been identified in eastern Mojos as well as other locations along the southern rim of Amazonia

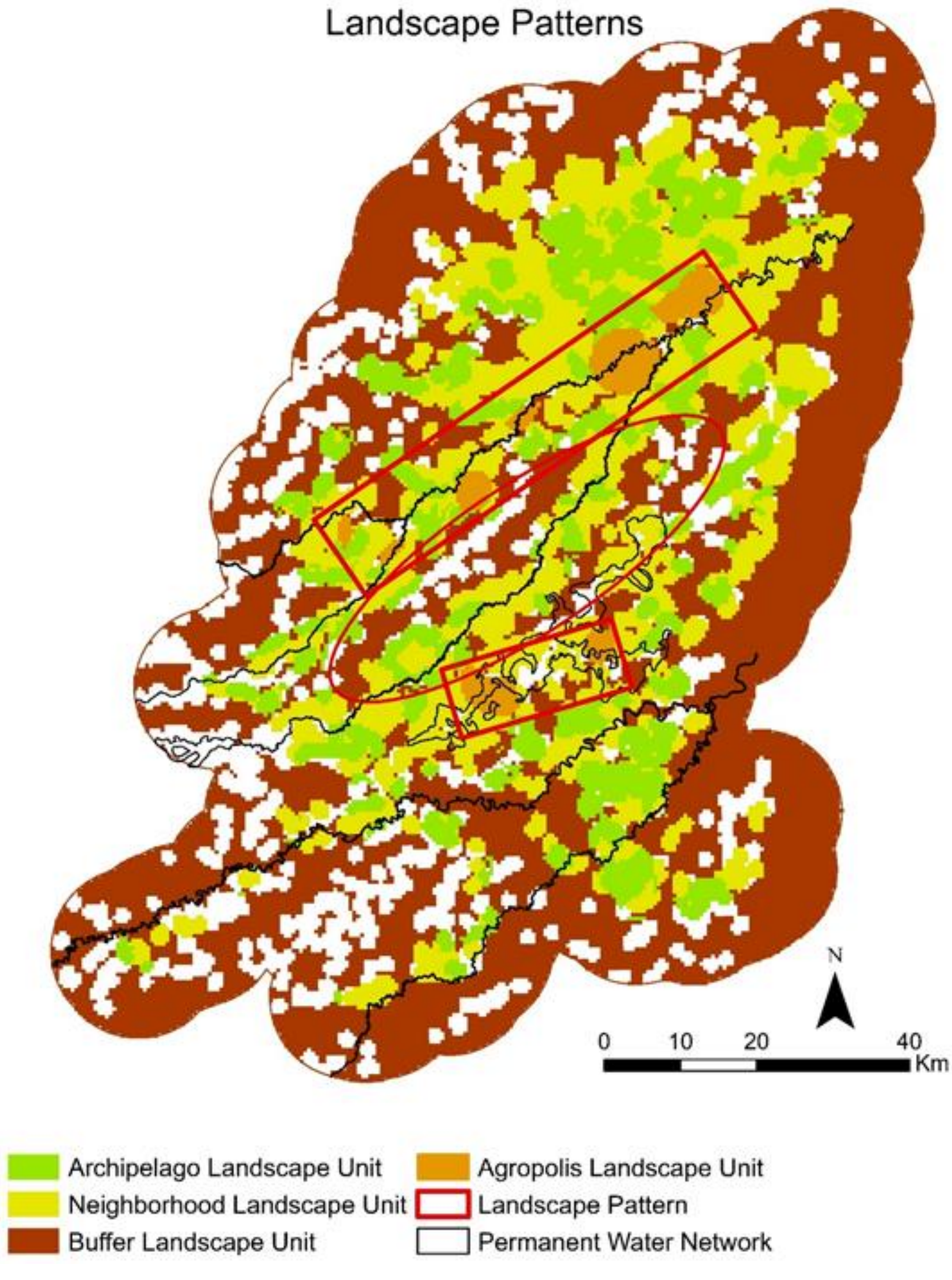


Figure 89: A transitional zone can be identified at the center of the study area based on the organization of Buffer Landscape Units surrounded by Neighborhood Landscape Units on all sides

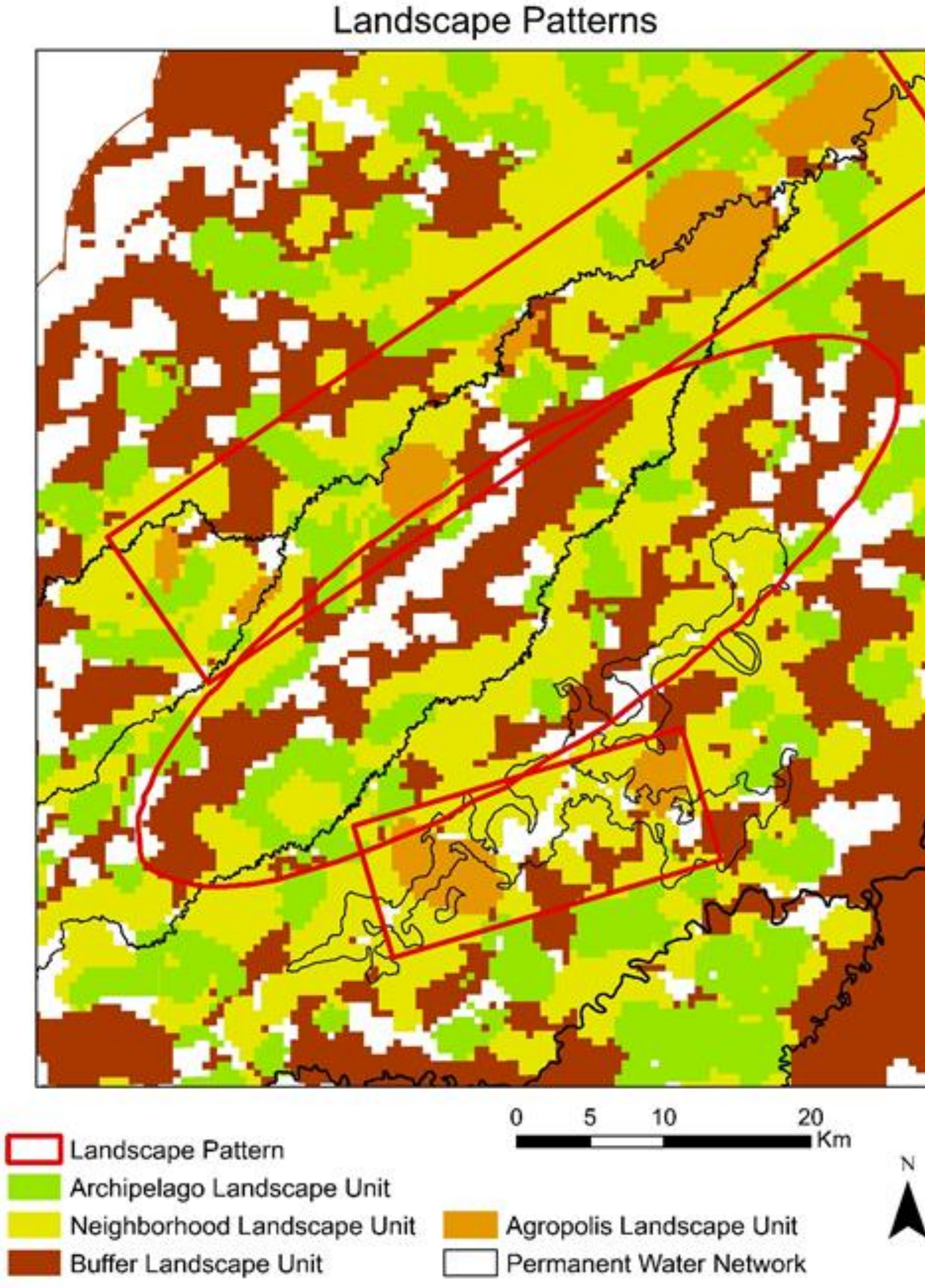


Figure 90: A transitional zone can be identified at the center of the study area based on the organization of Buffer Landscape Units surrounded by Neighborhood Landscape Units on all sides.

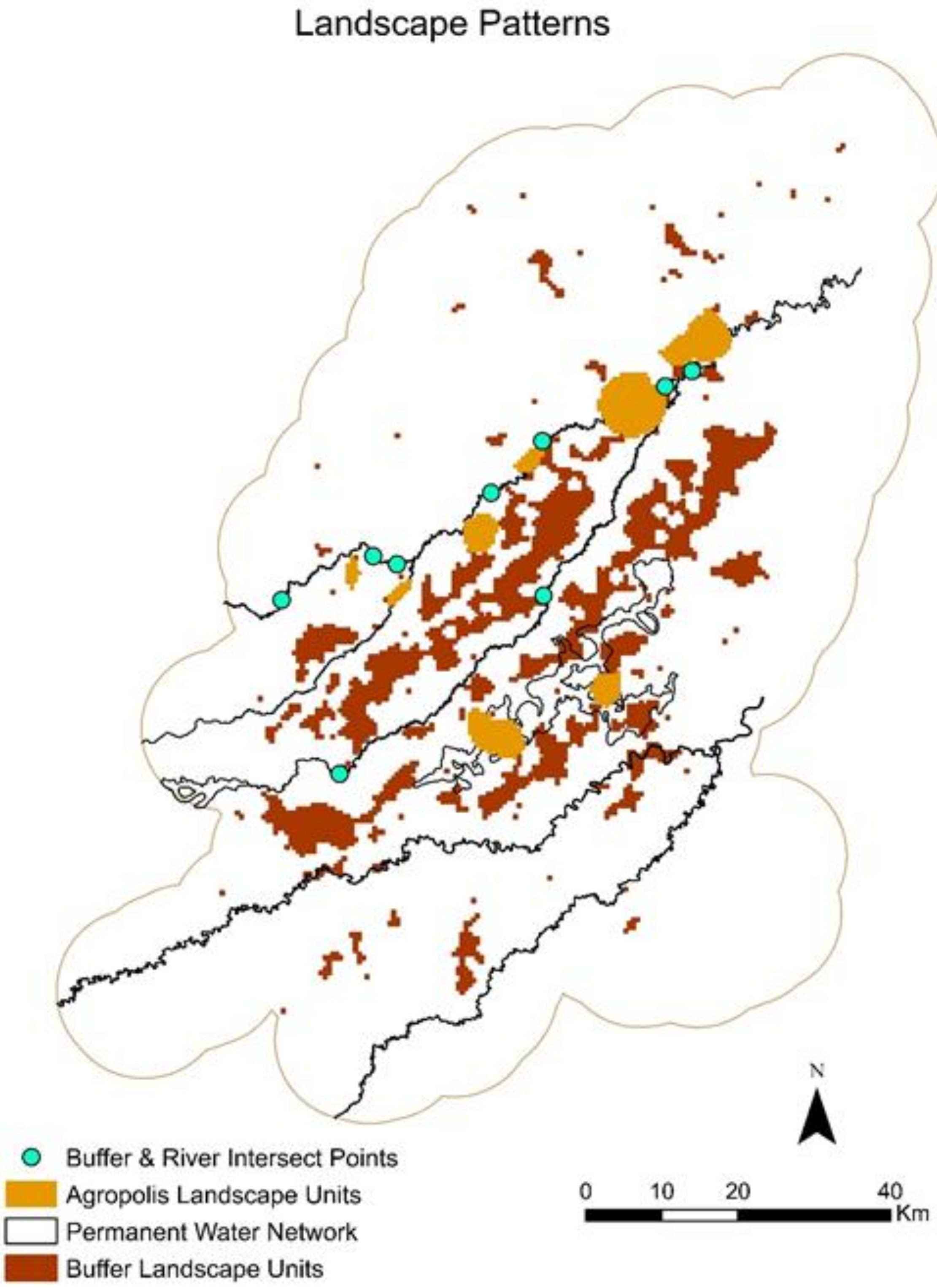


Figure 91: A transitional zone can be identified at the center of the study area based on the organization of Buffer Landscape Units surrounded by Agropolis Landscape Units on all sides. Buffer units only intersect the Omi river once in the center of this zone.

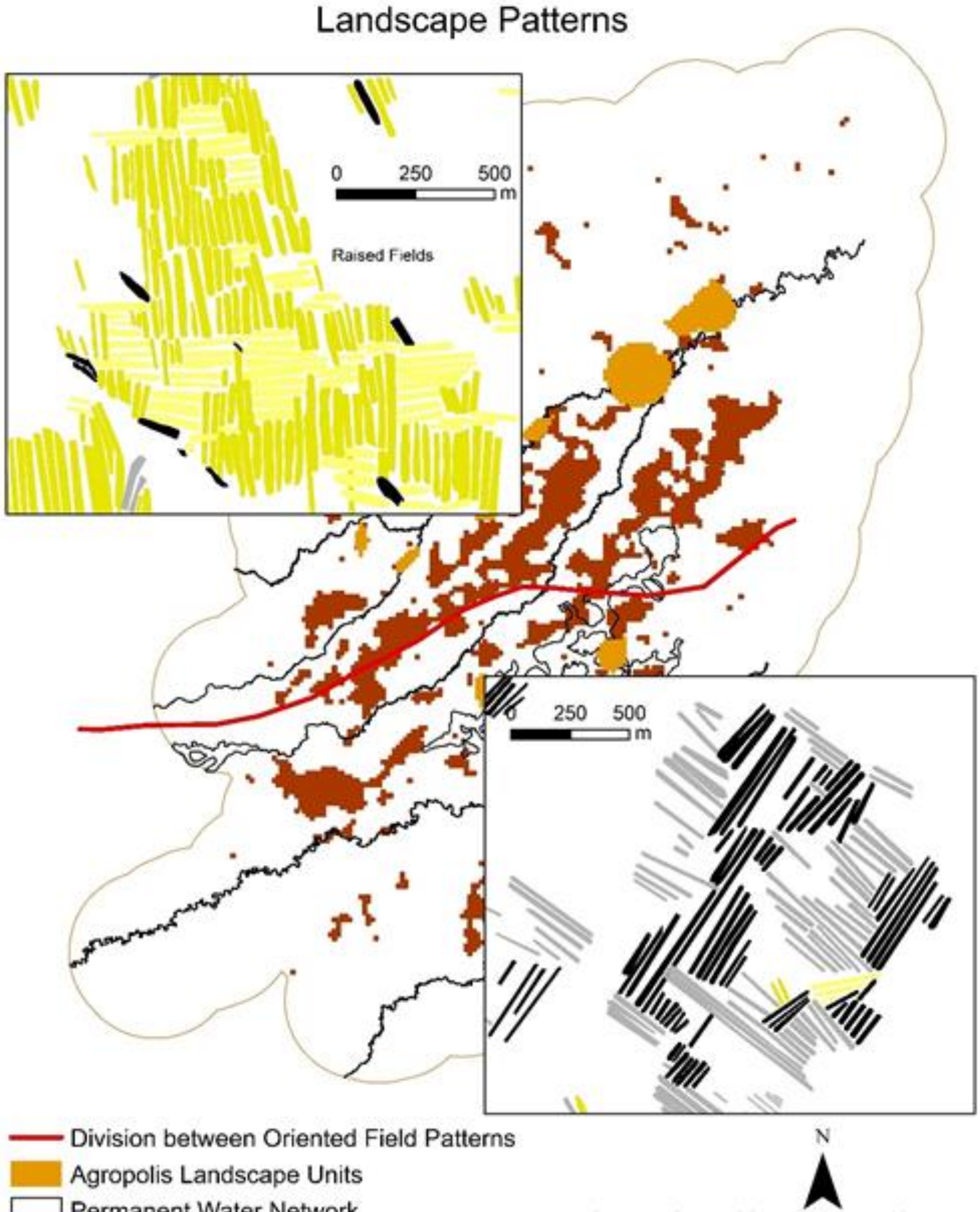


Figure 92: The transitional zone between regional settlement patterns coincide with a transition between dominant field orientations identified by Lee (2017). North of the division, fields are commonly oriented on a north/south or east/west axis. In the southern region fields are commonly oriented on a northeast/southeast or northwest/southwest axis.

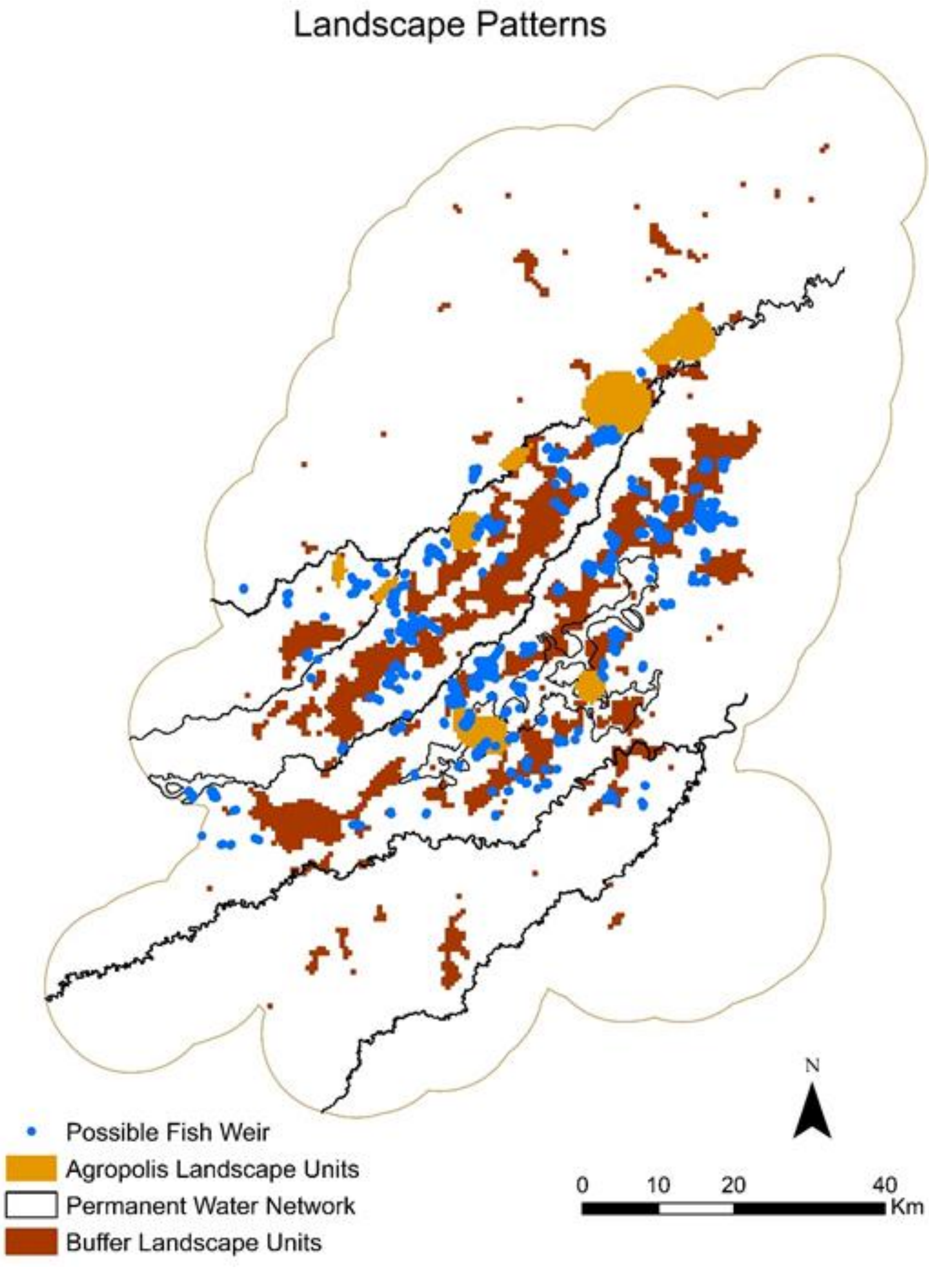


Figure 93: The transitional zone in this study overlaps with the distribution of fish weirs currently being digitized. This highlights the possibility that the raised field Neighborhoods were more thoroughly incorporated into other subsistence practices and possibly manipulating the movement of water and fish on a regional scale

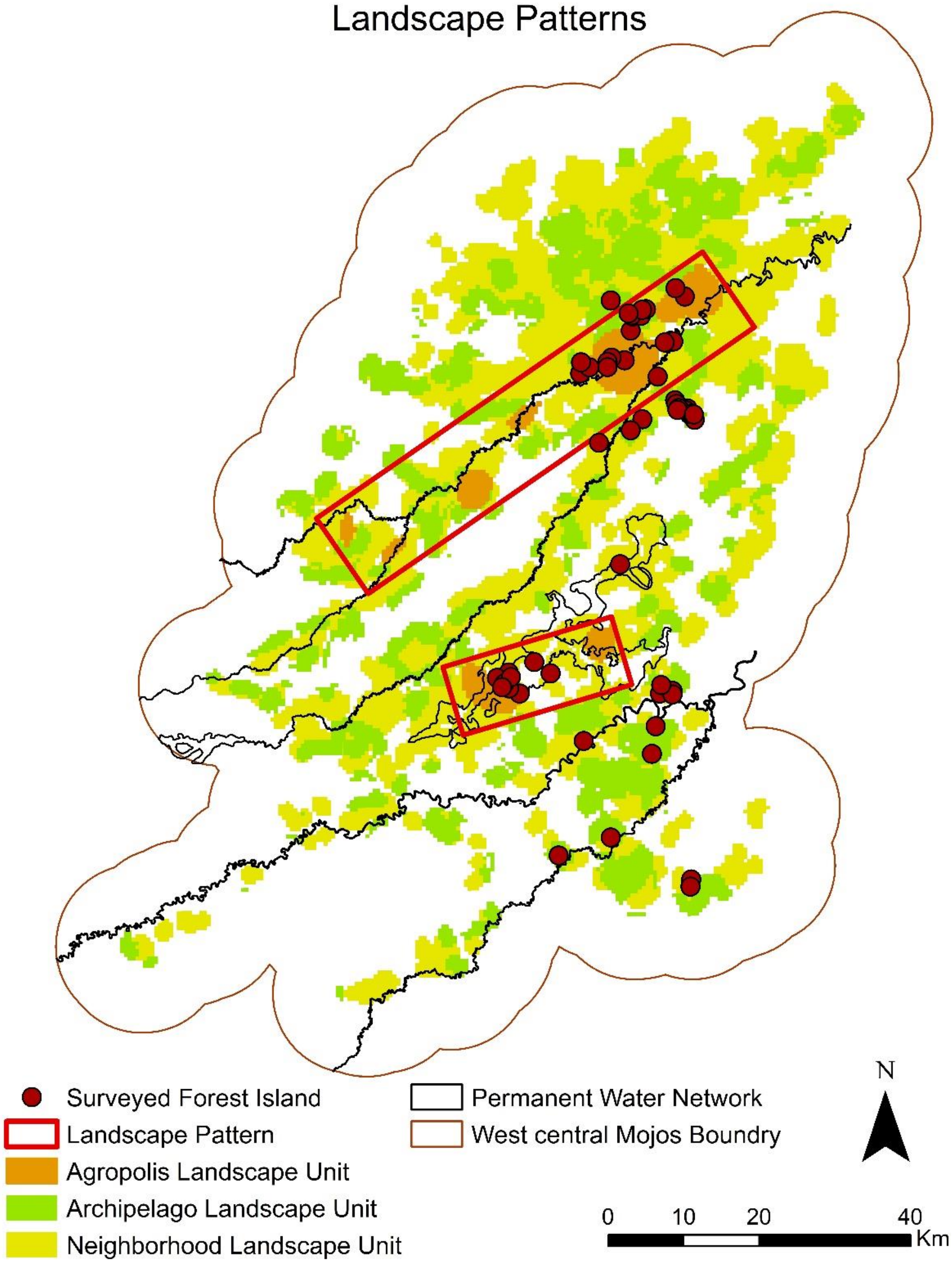


Figure 94: A map of the 55 forest islands that have been ground surveyed by archaeologists in west central Mojos.

APPENDIX B: TABLES

Table 1: Raised field Neighborhoods were buffered in increasing increments to demonstrate their distribution across west central Mojos. Walker (2018) defines west central Mojos as any area within 10km of a large raised field platform. A buffer of 4,151 meters is all that is required to combine all polygons representing field platforms into a single continuous polygon with no internal gaps.

Neighborhood Buffer Distance (m)	Neighborhood Count	Sum Area of Buffers (km^2)
20	4,444	283.9
150	913	868.6
250	493	1,255.5
500	188	2,089.2
1,000	56	3,374.4
1,500	15	271.1
2,000	7	5,073.4
2,500	4	5,667.0
3,000	3	6,163.7
3,500	3	6,588.6
4,000	3	6,951.5
4,151	1	7,050.4
10,000	1	10,288.1

Table 2: Neighborhood platform counts are placed in a list then divide into 5 natural breaks (Natural Jenks). A cut-off value between small and large Neighborhoods was selected based on the Neighborhood characteristics within these 5 categories. See Tables 3 – 5 for a further breakdown. Platform count was chosen as the defining characteristic over sum area given its ability to account for neighborhoods with numerous platforms but smaller individual platforms on average.

Natural Jenks (Break #)	Platform Count	Platform Sum Area (ha)
1	<26	<10
2	27 – 97	10 – 40
3	98 – 297	41 – 95
4	298 – 611	96 – 292
5	612 – 1,920	293 – 496

Table 3: Neighborhood platform counts are placed in a list then divide into 5 natural breaks (Natural Jenks) to examine the characteristics of Neighborhoods of different sizes. The goal was to select a cut-off value for large verse small Neighborhoods. There were only 6 Neighborhoods with more than 298 fields, creating a far too restrictive selection for identifying Agropolis Landscape Units with large forest islands. A selection of Neighborhoods with a field count above 27 would include more than 300 Neighborhoods and more than 75% of the total Neighborhood surface area in the project. The third break between these two values allows for a selection of Neighborhoods with significantly increased size but a limited enough distribution to still make reasonable interpretations from the data.

Neighborhoods Organized by Rank (Jenks) & Size (count)	**Neighborhood (count)**	**% of total Neighborhood count**	**Sum Neighborhood Area (m^2)**	**% of Sum Neighborhood Area**
Any	4,444	100	120,276,324	100
1: <26	4,128	92.9	41,944,850	34.9
2: 27 – 97	259	5.8	33,696,760	28.0
3: 98 – 297	48	1.1	23,376,612	19.4
4: 298 – 611	6	0.1	10,021,753	16.6
5: 612 – 1,920	3	0.1	11,236,350	9.3

Table 4: Neighborhood platform counts are placed in a list then divide into 5 natural breaks (Natural Jenks) to examine the characteristics of Neighborhoods of different sizes. Across the different breaks, platforms maintain a relatively standard size. The clustering of fields into larger groups does not appear to result in larger individual platforms.

Neighborhoods Organized by Rank (Jenks) & Size (count)	Average Neighborhood Sum Area (m^2)	Average Neighborhood Size (platform count)	Average Individual Platform Size (m^2)
Any	27,065 (*s* = 142,402)	9.9 (s = 48.1)	2,445 (*s* = 2,014)
1: <26	10,161 (*s* = 15,697)	4.1 (s = 4.6)	2,415 (*s* = 2,034)
2: 27 – 97	130,103 (*s* = 85,846)	46.6 (s = 18.1)	2,860 (*s* = 1,630)
3: 98 – 297	487,013 (*s* = 341,405)	156.1 (s = 42.8)	3,134 (*s* = 1,871)
4: 298 – 611	1,670,292 (*s* = 782,366)	539.7 (s = 66.1)	3,166 (*s* = 1,427)
5: 612 – 1,920	3,745,450 (*s* = 1,432,831)	1,484.0 (s = 308.8)	2,566 (*s* = 1,088)

Table 5: The near distances from a Neighborhood to other landscape features are compared for Neighborhoods of different sizes. The average distance between two Neighborhoods of the same rank triples when considering Neighborhoods with a field count of 98 or more compared to smaller Neighborhoods with only 27 or more fields. Larger Neighborhoods have more spacing between themselves but still have small Neighborhoods in close proximity.

Neighborhoods Organized by Rank (Jenks) & Size (count)	Average Distance from Neighborhood to Nearest Neighborhood (m)	Average Distance from Neighborhood to Nearest Permanent River (m)	Average Distance from Neighborhood to Nearest Forest Island (m)
None	136 (s = 214)	7,455 (s = 6,554)	1,252 (s = 1,140)
1: <26	172 (s = 243)	7,550 (s = 6,567)	1,266 (s = 1,159)
2: 27 – 97	1,034 (s = 1,517)	6,115 (s = 6,115)	1,079 (s = 889)
3: 98 – 297	3,405 (s = 5,565)	6,227 (s = 6,124)	961 (s = 641)
4: 298 – 611	5,446 (s = 6,815)	7,179 (s = 8,975)	1,496 (s = 535)
5: 612 – 1,920	5,139 (s = 3,962)	11,909 (s = 9,378)	1,244 (s = 566)

Table 6: The surface area of each forest island was placed in a list and divided into 5 statistical categories (Natural Jenks). The purpose of this process was to identify a cutoff size for identifying forest islands that are significantly larger than the other forest islands in the data set. See Tables 7 & 8 for a further breakdown. Ultimately the third break of 26.3ha and higher was chosen as the cutoff for large forest islands.

Natural Jenks (Break #)	Forest Island Surface Area (ha)
1	<7.41
2	7.41 – 26.2
3	26.3 – 66.5
4	66.6 – 135.5
5	135.6 – 318.2

Table 7: The surface area of each forest island was placed in a list and divided into 5 statistical categories (Natural Jenks). The purpose of this process is to identify a cutoff size for identifying forest islands that are significantly larger than the other forest islands in the data set. Selecting all forest islands above the second break reduces the forest island count from 1,940 to 1,676. This significantly reduces the forest islands that could be considered large; however, it accounts for less than a third of the total surface area of forest in the study area.

Forest Islands Organized by Rank (Jenks) & Size (ha)	Forest Island (count)	Forest Island Average Size (ha)	Forest Island Sum Area (ha)	% of Total Forest Island Count	% of Total Forest Island Area
All	1,940	4.5 (s = 13.6)	8,786	100	100
1: <7.41	1,676	1.6 (s = 1.6)	2,715	86.3	30.9
2: 7.41 – 26.2	204	13.2 (s = 4.7)	2,703	20.9	30.78
3: 26.3 – 66.5	51	39.3 (s = 10.6)	2,002	2.6	22.8
4: 66.6 – 135.5	9	94.2 (s = 22.7)	848	0.5	9.7
5: 135.6 – 318.2	2	306 (s = 12.5)	611	0.1	7.0

Table 8: The surface area of each forest island was placed in a list and divided into 5 statistical categories (Natural Jenks). The purpose of this process is to identify a cutoff size for identifying forest islands that are significantly larger than the other forest islands in the data set. The distance between forest islands of the same rank triples between the second and third breaks. The distance between every raised field platform and the nearest forest island was also measured. Those forests that were identified as the closest forest island to a Neighborhood are listed here as 'Farming Forest Islands.' Farming forest islands are expanded upon in table 9 below.

Forest Islands Organized by Rank (Jenks) & Size (ha)	**Average Distance from Forest Island to Nearest Forest Island of Same Rank(m)**	**Average Distance from Forest Island to Nearest Permanent River (m)**	**Average Distance from Farming Forest to All Associated Field Platforms (m)**	**Farming Forest Islands (count)**
All	546 (*s* = 686)	7,878 (*s* = 7,188)	839 (*s* = 683)	846
1: <7.41	636 (*s* = 711)	7,693 (*s* = 6,882)	869 (*s* = 704)	700
2: 7.41 – 26.2	1,687 (*s* = 2,097)	9,162 (*s* = 9,095)	669 (*s* = 506)	114
3: 26.3 – 66.5	4,795 (*s* = 6,203)	8,307 (*s* = 7,793)	829 (*s* = 683)	26
4: 66.6 – 135.5	6,640 (*s* = 9,798)	8,000 (*s* = 5,738)	704 (*s* = 424)	5
5: 135.6 – 318.2	2,067 (*s* = 0)	17,539 (*s* = 1,349)	117 (*s* = 83)	2

Table 9: The distance between every raised field platform and the nearest forest island was measured. Those forests that were identified as the closest forest island to a Neighborhood are listed here has 'Farming Forest Islands.' 'Other Forest Islands' are not meant to represent forests that are not participating in raised field farming. In many instances raised field platforms are in the close proximity of several forest islands. More than half of the forest island surface area in the study could be associated to at least one raised field that was closer to that forest than any other forest. Large forest islands also show stronger associations with raised field platforms given the larger average size of Farming Forest Islands identified here.

Forest Island Near Distance Category	Forest Island (count)	Forest Island Sum Area (ha)	% of Forest Island Total (count)	% of Forest Island Total Area	Average Forest Island Size (ha)
Farming Forest Island	847	4,755	43.7	54.1	5.6 (*s* = 17.8)
Other Forest Islands	1,093	4,031	56.3	45.9	3.7 (*s* = 9.1)

Table 10: The distance between every raised field platform and the nearest forest island was measured. Those forests that were identified as the closest forest island to a Neighborhood are listed here has 'Farming Forest Islands.' Farming Forests can be found at great distances from the permanent rivers but the average distance between a raised field platform and its nearest forest is still only a few hundred meters. There are some forests that are at great distances from raised field platforms, however, this is to be expected given the definition of west central Mojos which includes up to 10km of the area surrounding the raised fields themselves. With a 10km maximum distance, an average distance of 3,725 for 'Other Forests' is still quite low and within the range of suitable distances applied to the Buffer Landscape Units that represent areas less associated with either forest islands or raised fields.

Forest Island Type	Average Distance from Forest Island to Nearest Forest Island (m)	Average Distance from Forest Island to Nearest Permanent River (m)	Average Distance from Forest Island to all associated Platforms (m)	Average Distance from Forest Island to Nearest Neighborhood (m)
Farming Forest Islands	568 (*s* = 687)	6,617 (*s* = 6,030)	839 (*s* = 682)	330 (*s* = 439)
Other Forest Islands	530 (*s* = 684)	8,855 (*s* = 7,831)	n/a	3,725 (*s* = 3,098)

Table 11: All forest islands in the project were sorted into three groups. The smallest forest islands were used to identify Archipelago Landscape Units. The largest forest islands were used to identify Agropolis Landscape Units. All forests that are too large for the Archipelago units and too small for the Agropolis units were part of a third undefined group. These mid-size forest islands were used to identify Buffer Landscape Units and represent the undefined spaces in the final map of all combined Landscape Units (Figure 57).

Forest Category & Size Range (ha)	Forest Island (count)	Forest Island Sum Area (ha)	% of Forest Island Total (count)	% of Forest Island Total Area (ha)	Farming Forests (count)
Small: <= 0.8	735	318	37.9	3.6	278
Large: >= 26.3	60	3,368	3.1	38.3	32
Undefined: >.8 & < 26.3	1,145	5,100	59.0	58.1	536

Table 12: The group of Undefined forest islands are too large to identify Archipelago Landscape Units and too small to identify Agropolis Landscape Units. The distances between forest islands and other landscape features does not change significantly for Undefined forests. These forests are distributed among both small Archipelago forest islands as well as large Agropolis forest islands.

Forest Category & Size Range (ha)	Average Distance from Forest Island to Nearest Forest Island of Same Category (m)	Average Distance from Forest Island to Nearest Permanent River (m)	Average distance from Farming Forest to All Associated Raised Field Platforms (m)
Small: <= 0.8	639 (s = 698)	6,588 (s = 5,260)	929 (s = 767)
Large: >= 26.3	450 (s = 922)	8,651 (s = 7,682)	788 (s = 651)
Undefined: >.8 & < 26.3	491 (s = 657)	8,665 (s = 8,059)	796 (s = 631)

Table 13: The length of the rivers including meanders are measured through a 40km x 6km sample block to show how meanders can alter travel distance in the study area. The sample block was created by clipping out a long strip of the Iruyañez between its confluence with the Omi and another large confluence approx. 40km upstream to the southwest. The minimum bounding geometry tool produced a rectangle around this section of river 40km long by 6km wide. This polygon was adjusted to exact dimensions of 40km x 6km and then georeferenced over each of the four major rivers in the study area so that the river enters the sample box at a 6km leg to the southwest and exits the sample box at the opposite 6km leg to the northeast. This method demonstrates how the meanders in the rivers alter the length of the total river needed to pass through the entire sample block.

Permanent Water Network	Line Length (m) Through 40km Sample Block = Meander Length	Average Width of River Surface Visible Between Forested Banks (m)	Meander Ratio (Meander Length / 40,000m)
Iruyañez	81,304	30	2.0
Omi	104,881	5	2.6
Yacuma	75,494	70	1.8
Rapulo	75,183	65	1.9
Kinato	N/A	N/A	N/A

Table 14: The total size of each Landscape Units is measured and compared to the total size of the study area. While nearly enough surface area of Landscape Units has been created to cover the entire study area, this does not account for any overlap between Landscape Units.

Landscape Units	Sum Area (Km^2)	% of Total Study Area (Unit Sum/10,281km^2 * 100)
Neighborhood	3,378	32.9
Buffer	4,944	48.1
Archipelago	1,368	13.3
Agropolis	183	1.7
All Landscape Units	9,873	96
Study Area	10,281	100

Table 15: The characteristics of field Neighborhoods within Archipelago Landscape Units are compared to characteristics of Neighborhoods within Agropolis Landscape Units. Agropolis Landscape Units contain 7 times as much surface area of raised field Neighborhoods as Archipelago Landscape Units.

Landscape Units	Unit (count)	Average Sum Neighborhood Area Within Unit (km2)	Average Neighborhood Size Within Unit (count)	Average Neighborhood Area (m2)	Average size of individual platform (m2)
Archipelago	109	0.32 (*s* = 0.63)	17.9 (*s* = 31.6)	68,022 (*s* = 174,748)	3,112 (*s* = 1,709)
Agropolis	9	2.1 (*s* = 2.7)	25.8 (*s* = 16)	89,691 (*s* = 57,036)	3,244 (*s* = 1,216)

Table 16: The characteristics of Neighborhoods within Archipelago Landscape Units are compared to characteristics of Neighborhoods within Agropolis Landscape Units. Despite being comprised by definition of significantly larger forest islands, the Agropolis Landscape Units have a lower ration of forest island surface area to Neighborhood surface area given how much more expansive Neighborhood Landscape Units are within the Agropolis landscape communities. While Archipelago forest islands are much smaller than Agropolis forest islands they also have a higher ratio on average of the individual size of a forest island compared to the average size of an individual raised field neighborhood. In Agropolis Landscape Units, forest islands are larger but the Neighborhoods are exponentially larger as well compared to Archipelago Landscape Units.

Landscape Units	Average Ratio of Sum Forest Island Area to Sum Unit Area	Average Ratio of Sum Forest Island Area to Sum Neighborhood Area	Average Ratio of Average Forest Island Area to Sum Neighborhood Area	Average Ratio of Average Forest Island Area to Average Neighborhood Sum Area	Average Ratio of Average Forest Island Area to Average Platform Area
Archipelago	0.01 (*s* = 0.02)	3.4 (*s* = 13.3)	0.52 (*s* = 1.66)	1.0 (*s* = 2.1)	0.78 (*s* = 0.55)
Agropolis	0.03 (*s* = 0.02)	1.98 (*s* = 3.8)	0.33 (*s* = 0.64)	0.22 (*s* = 0.38)	73 (*s* = 151)

Table 17: The characteristics of Neighborhoods within Archipelago Landscape Units are compared to characteristics of Neighborhoods within Agropolis Landscape Units. Within Archipelago Landscape Units farmers are not travelling any further to tend their fields than they would within an Agropolis Landscape Unit. However, Neighborhoods within Archipelago Landscape Units can be more than 10km from a permanent river. Agropolis Landscape Units are also associated with large Neighborhoods of raised fields that span several kilometers out into the savanna, providing a large standard deviation for their average distance measurements.

Landscape Units	Average Distance from Farming Forests to All Associated Platforms (m)	Average Distance from All Platforms to Nearest Permanent River (m)
Archipelagos	697 (*s* = 303)	5,938 (*s* = 5,695)
Agropolis	924 (*s* = 279)	3,344 (*s* = 2,916)

Table 18: The characteristics of Neighborhoods within Archipelago Landscape Units are compared to characteristics of Neighborhoods within Agropolis Landscape Units. Agropolis Landscape Units contain more than 3 times as much forest island surface area than Archipelago Landscape Units.

Landscape Units	Unit (count)	Average Sum Forest Island Area Within Unit (ha)	Average Number of Forest Islands Within a Unit (count)	Average Size of Individual Forest Islands Within Unit (ha)
Archipelago	109	22.7 (*s* = 39.0)	8.1 (*s* = 7.8)	2.7 (*s* = 2.7)
Agropolis	7	72.7 (*s* = 73.9)	9.8 (*s* = 8.7)	13.2 (*s* = 22.6)

Table 19: The characteristics of Neighborhoods within Archipelago Landscape Units are compared to characteristics of Neighborhoods within Agropolis Landscape Units. For the Agropolis Landscape Units raised fields are slightly closer in proximity than the Archipelago Landscape Units. This value of 271 meters is much lower than that measured from every platform to the closest forest (Table 17: 924m). This is because Neighborhoods are extensive in Agropolis communities, spanning more than a kilometer across the landscape. Measuring the distance to a single platform adjacent to the forest island does not represent the distances that would be required to travel to the opposite end of the Neighborhood as the larger value of 924m demonstrates. Note that values in this table representing the distances between forest island and neighborhood are for farming forests only. This is for comparison with table 17 which measures the distances to only those forest islands that are the closest forest island to a raised field platform.

Landscape Units	Avg Distance from Farming Forest to Nearest Neighborhood (m)	Average Distance from Forest Island to Nearest Forest Island (m)	Average Distance from Forest Island to Permanent River (m)
Archipelago	693 (*s* = 532)	757 (*s* = 842)	5,762 (*s* = 5,354)
Agropolis	271 (*s* = 170)	547 (*s* = 307)	3,093 (*s* = 3,367)

Table 20: The characteristics of the Agropolis Landscape Units and their containing Neighborhoods are examined and compared to each other. The Agropolis Landscape Units along the Iruyañez river in the northern portion of the study area are much more abundant than the ones in the south. There is 4 times as much Neighborhood surface area in the north. While Neighborhoods in the north may be bigger, the average size of an individual platform does not show the same pattern. The smallest fields on average are found within Agropolis 1 (El Cerro) though large fields are still found in other areas along the Iruyañez. The largest fields on average are constructed in the Quinato wetland to the south though this is not the only place that large platforms are found. There are clear distinctions between the Northern and Southern groups as well as some variability within the groups to the north.

Agropolis Unit ID and Regional Location	Total Unit Area (km2)	Total Number of field Neighborhoods Intersecting Unit (count)	Total Area of field Neighborhoods Intersecting unit (km2)	Average Area of Individual field Neighborhood Within Unit (m2)	Average size of Individual Field Platform (m2)
1: (North)	40.8	98	3.3	33,664 (*s* = 101,132)	1,541 (*s* = 1,207)
2: (North)	58.8	58	11.0	189,449 (*s* = 742,028)	3,827 (*s* = 3,518)
3: (North)	7.8	5	0.7	137,519 (*s* = 95,098)	2,874 (*s* = 142)
4: (North)	18.3	14	1.3	89,492 (*s* = 137,379)	4,424 (*s* = 2,921)
5: (North)	10.5	4	0.05	11,583 (*s* = 10,889)	2,224 (*s* = 891)
6: (South)	13.8	14	1.5	107,614 (*s* = 253,727)	5,382 (*s* = 2,635)
7: (South)	33.0	48	2.8	58,518 (*s* = 154,272)	3,694 (*s* = 2,616)

Table 21: While similar amounts of forest area is distributed among the northern and southern Agropolis Landscape Units, the southern Agropolis Landscape Units contain nearly all the forest island area clustered into a single Agropolis. Agropolis Landscape Units in the north have their forest area distributed across a much larger area and are divided into individual Units.

Agropolis Unit ID and Regional Location	Total Forest Island Area Within Unit (ha)	Total Number of Forest Islands Within Unit (count)	Average Size of Individual Forest Island Within Unit (ha)	Ratio of Sum Forest Island Area Within Unit to Unit Area
1: (North)	136.7	2	68.3	0.030
2: (North)	48.0	14	3.4	0.008
3: (North)	0.6	1	0.6	0.001
4: (North)	62.0	13	4.8	0.034
5: (North)	24.3	6	4.1	0.023
6: (South)	14.4	5	2.9	0.010
7: (South)	222.6	28	7.9	0.067

Table 22: The characteristics of the Agropolis Landscape Units and their containing Neighborhoods are examined and compared to each other. All Agropolis Landscape Units have relatively short average distances between their containing Neighborhoods and nearest forest islands. However, in the south the distance between the Neighborhoods and the nearest river increases to more than 6km on average. This reflects the organization of Agropolis Landscape Units in the north along the Iruyañez river while in the south the units are organized at the midpoint between the permanent rivers along the Quinato wetland.

Agropolis Unit ID and Regional Location	Average Distance from Farming Forests to All Associated Platforms (m)	Avg Distance from Forest Island to Nearest Neighborhood (m)	Average Distance from Platforms Within Unit to Nearest Permanent River (m)	Avg Distance from Forest Islands Within Unit to Nearest Forest Island (m)	Avg Distance from Forest Islands Within Unit to Nearest Permanent River (m)
1: (North)	1,017 (*s* = 731)	3 (*s* = 3.5)	2,087 (*s* = 958)	962 (*s* = 347)	2,861 (*s* = 1,298)
2: (North)	935 (*s* = 551)	87 (*s* = 125)	1,140 (*s* = 616)	708 (*s* = 553)	747 (*s* = 658)
3: (North)	1,542 (*s* = 340)	328 (*s* = 0)	620 (*s* = 171)	972 (*s* = 0)	191 (*s* = 0)
4: (North)	643 (*s* = 276)	322 (*s* = 250)	2,151 (*s* = 892)	336 (*s* = 438)	1,286 (*s* = 1,065)
5: (North)	858 (*s* = 108)	523 (*s* = 307)	1,782 (*s* = 980)	197 (*s* = 173)	107 (*s* = 82)
6: (South)	746 (*s* = 433)	427 (*s* = 423)	8,781 (*s* = 527)	432 (*s* = 258)	867 (*s* = 1,444)
7: (South)	724 (*s* = 647)	211 (*s* = 181)	6,845 (*s* = 2,107)	226 (*s* = 352)	7,792 (*s* = 1,132)

Table 23: The total amount of overlap between the different Landscape Units in square kilometers is compared.

	Neighborhood	**Buffer**	**Archipelago**	**Agropolis**
Archipelago	977.63	159.23	X	X
Agropolis	168.75	8.75	33.75	X

Table 24: The average size of individual overlaps between different Landscape Units in square kilometers is compared. Overlaps between Archipelago and Neighborhood Landscape Units average 9 km^2 in size. Agropolis Landscape Units have almost 3 times as much overlap with Neighborhood Landscape Units on average.

	Neighborhood	**Buffer**	**Archipelago**	**Agropolis**
Archipelago	9.05 (s = 9.50)	2.56 (s = 6.79)	X	X
Agropolis	24.11 (s = 17.40)	0.73 (s = 0.84)	6.75 (s = 6.56)	X

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