

Chapter 26

Land Cover Pattern and Road Types in Lop Buri Province, Thailand, 1989–2006

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Abstract

Road development leads to several benefits to a region, such as accessibility for people and resources to market areas, farmland, forests, and residential areas. Such a development has an important role in the economic and social development of a nation. Road network development fosters economic growth by providing a means of transportation for people and goods. Although the development of roads brings an overall benefit to society by improving overall connectivity, its impact on land cover is less well understood. This study aims to determine the relationships between road types and land cover in Lop Buri Province, Thailand. The research questions are (1) what is the pattern of land cover associated with different road types? and (2) what is the pattern of change in terms of land cover distribution within a road type? The analysis relies on descriptive statistics and the use of GIS and remote sensing technology. The study concludes that with the improvement of the road network development that aimed to improve social and economic development over the past two decades, the distribution of land cover along these types of roads has changed over time. The loss of forest and increase in upland crops has led to changes in local climate and local hydrology as well as the loss of biodiversity.

Keywords Road network • Land cover • Lop Buri Province • GIS • Economic development

26.1 Introduction

Road development is an agent of land cover change that results from disturbances within a landscape caused by human activities (Almeida 2005; Glover and Simon 1975; Hawbaker et al. 2005; Lugo and Gucinski 2000). This change occurs because

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road development increases access for humans to the land (Saunders et al. 2002). However, the impact of roads on land cover is unclear. Road network development has contributed to land cover change in Thailand, particularly in the northern, north-eastern, and central regions (Cropper et al. 1999; Hafner 1970; Hughes 1971).

The development of a road network that evolves from foot trails to complex highway systems brings benefits to human civilizations (Lugo and Gucinski 2000). As roads provide access to resources such as market areas, farmland, forests, and residential areas, they play an important role in economic and social development. First, road network development fosters economic growth by providing a means of transportation for goods (e.g., agricultural products) to local, regional, or international markets in less time and with lower costs. Second, roads supplement social development by providing access to services such as education, employment centers, and healthcare centers (Queiroz and Gautam 1992; Windle and Cramb 1997). Although roads bring benefits to human civilizations, they fragment habitats, facilitate the spread of invasive species, alter hydrology, alter the climate, and influence the patterns of land cover (Dale 1997; Geist and Lambin 2002; Hawbaker et al. 2005; Lambin et al. 2001; Trombulak and Frissell 2000). Thus, impacts of roads on the ecology of a region are of concern in tropical areas where the road infrastructure needed to handle economic and social development in a developing country such as Thailand is expanding rapidly into areas of high biodiversity such as the forests.

Previous studies have used many measures such as distance to roads (Chomitz and Gray 1996; Coffin 2009; Patarasuk and Binford 2012), connectivity indices (Coffin 2007; Rojnkureesatien 2006), and type of road cover (Layton 1996; Verburg et al. 2004) to assess the relationships between road network and land cover pattern. The most commonly used as a measure of land cover change associated with roads is distance to roads. Distance to a road is a measure of accessibility to the land. The closer the distance to roads, the better the accessibility to land. Thus, more land conversion occurs near roads. This phenomenon follows the concept of distance decay (Li and Yeh 2004; Walsh et al. 2001). For example, in the Brazilian Amazon region, road network development results in a fishbone structure. Road development contributes to vast deforestation as a result of agricultural activities. For example, Alves et al. (1999) estimated that 79 % of the forests in the Central Rondônia in the Western Brazilian Amazon was cleared within 12.5 km of roads between 1977 and 1995. Next, the link between distance to roads, road connectivity, and land cover change has been studied by Rojnkureesatien (2006). As road networks develop, the connectivity usually increases. Rojnkureesatien (2006) showed that larger patches of forests are cleared within 500 m of roads compared to those within 1,500 m.

The type of roads, which includes hierarchy and surface type, can be used as a proxy for land accessibility and patterns of land cover (Forman et al. 2003; Layton 1996; Verburg et al. 2004). Hierarchy of roads refers to national highways (or interstates), provincial highways, and local roads. Layton (1996) states that accessibility to land is less on a highway compared to a local road. A highway or an interstate, which is usually more than two lanes wide, provides the highest travel speed, serves longer distances, and usually connects major cities or large urban areas. This type

of road connects high population and major trade centers (e.g., urban/suburban development) where the land cover usually impervious with less vegetation cover found. In comparison, local roads, which are usually two lanes wide, constitute the lowest hierarchy. Local roads connect residential houses or farmlands; these roads are usually surrounded by agricultural landscapes (Forman et al. 2003; Layton 1996). Furthermore, road type by surface type, either loose (unpaved) or hard (paved), portrays different degrees of accessibility to the land. For example, loose-surface roads typically are not easily accessible during the rainy season because the ground is too soft to accommodate the large vehicles that transport agricultural products in agricultural areas. In contrast, hard-surface roads are usable in all types of weather and can accommodate larger vehicles (Laurance et al. 2002; Verburg et al. 2004). Evidence from previous studies shows that when road surfaces are upgraded from unpaved to paved, land cover conversion is intensified. Examples can be seen from case studies in the region of Rondônia State, Brazil. The total length of paved roads increased from 1,434 km in 1979 to 25,324 km in 1988 (Dale et al. 1994). Paved roads encouraged new settlers to migrate to Rondônia and ultimately led to land cover conversion. In particular, especially along BR-364, much of the land conversion was from forests to agriculture and built-up areas. Between 1978 and 1987, 660 % of the forests along this BR-364 had been converted because of this road surface upgrade (Imbernon 2007; Roberts et al. 2002).

The road network in Thailand has been extensively developed since World War II. The purpose of road network development after the war was to support military movement for national security as well as to enhance its neighboring country contacts, especially the international relationships with Laos (Cropper et al. 1999; Kakizaki 2002). Since 1961, as part of the National Plan, the goal of road network development is to foster social and economic development as well as aiming to alleviate poverty (Puri 2006). Particularly, road building was planned to facilitate moving commercial crops from farmlands to market areas and to major cities for distribution to overseas markets (Rojnkureesatien 2006; Kermel-Torres et al. 2004). In Lop Buri, road network development was started in the 1930s by General Por Piboonsongkram, who established Lop Buri as a military town. As a result, Lop Buri has become the center for economic development within the upper Central Region of Thailand (Office of Information and Technology: Thepsatri Rajabhat University 2008). For the past several decades, ongoing road construction and improvement have occurred within the province. For example, National Highway No. 1, which is one of the most important of the four national highways in Thailand, passes through the province (Department of Highways District 1 Lop Buri 2008; Lop Buri Provincial Office 2006) (Fig. 26.1). This highway has a significant role in land transportation connecting Bangkok (the capital city of Thailand) with Lop Buri and the northern regions of Thailand; it is the main arterial for transporting agricultural products to the capital city.

This study aims to determine the relationships between road types and land cover in Lop Buri province. The main research questions are (1) what is the pattern of land cover associated with different road types? and (2) what is the pattern of change in terms of land cover distribution within a road type? The hypotheses are that

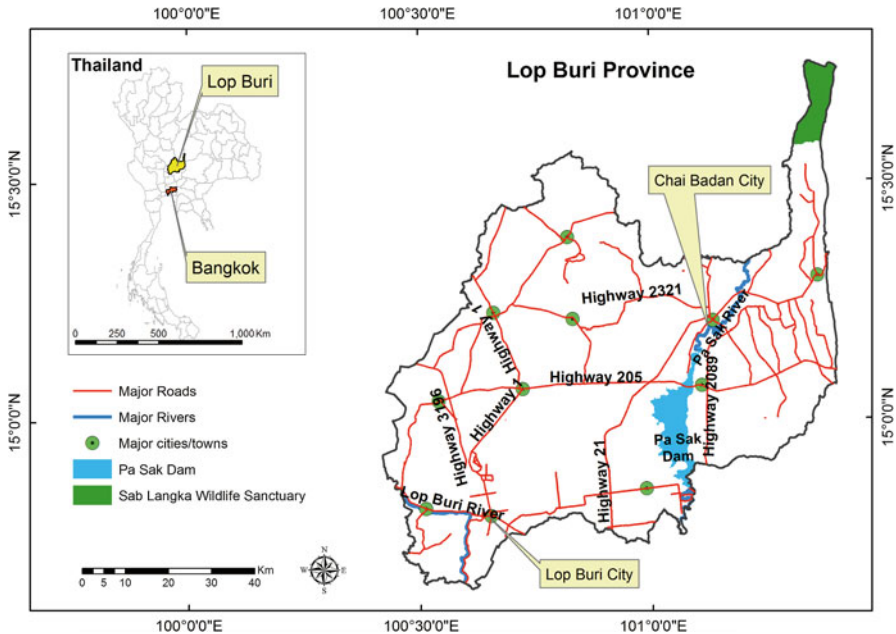


Fig. 26.1 The study area

(1) built-up areas have larger distribution along highways compared to local roads, (2) local roads have a higher distribution of agricultural landscape compared to built-up areas, and (3) larger amounts of forest cover are converted to agricultural land along local roads. The analysis relies on descriptive statistics and the use of Geographic Information System (GIS) and remote sensing technology.

26.2 Methods

26.2.1 Study Area

Lop Buri Province is located in the Central Region of Thailand (Fig. 26.1). It is approximately 150 km north of Thailand's capital city, Bangkok. The province has a land area of 6,600 km². Lop Buri province lies between 14°39'N and 15°35'N latitude and between 100°24'E and 101°26'E longitude. This province has a geographic advantage because it is a gateway among the Northern Thailand, Central Thailand, and Northeastern Thailand regions.

Lop Buri Province is considered as one of the wealthier provinces in Thailand (Felkner and Townsend 2004). The province's population in 2008 was 753,470. Lop Buri City is the most populated district with a population of 249,620, followed by

Chai Badan City, which has a population of 90,182. These two districts are the most important centers of economic activity in the province (Lop Buri Provincial Office 2010).

The elevation ranges from 5 to 750 m above sea level. The province has a subtropical climate influenced by monsoons. May to October is the rainy season, influenced by the southeast monsoon from the Indian Ocean. Rainfall in the province is bimodal. The greatest amount of rainfall is in September and the second greatest is in May. For the 30-year span from 1961 to 1990, the average amount of rainfall was 170 mm in May and 280 mm in September. November and April are dry months, influenced by the northeast monsoon from China. The average minimum temperature from 1961 to 1990 was 23.3 °C and the maximum was 33.3 °C. The hottest month is April and the coldest is December/January (Lop Buri Provincial Office 2006; Thai Meteorological Department 2008; Worakawin 2003).

The landscape is mainly composed of agricultural areas, with the major land cover being rice paddies and upland crops (e.g., cassava, sugarcane, maize, sunflowers). Forests, water, plantation, and built-up areas also constitute the provincial landscape. The land cover has undergone considerable alteration during the past several decades, particularly the change from forest to upland crops. This change was experienced by about 15 % of the entire province between 1989 and 2006. Other notable land cover changes in the area include rice paddies to upland crops (8 % of the study area), forest to rice (3 % of the study area), and forest to built-up areas (1 % of the study area) (Patarasuk and Binford 2012).

The road network consists of national highways, provincial highways, and local roads. The highways area paved; however, most of the local roads are not. Furthermore, the road network density is not evenly distributed throughout the province. The greatest densities are found in the southwestern and northern portions of the province. Toward the end of the 1990s, some roads were removed following the construction of the Pa Sak Dam, which was completed in 1999.

26.2.2 Land Cover Data

Land cover data used in the study were based on a previous study by Patarasuk and Binford (2012). These authors used a hybrid method classification process. Landsat images dated 20 January 1989 (TM 4), 10 March 1998 (TM 5), and 8 March 2006 (ETM+) were used to derive the land cover information. Six land cover classes were used: forest, water, plantation, rice, upland crops (e.g., cassava, sugarcane, maize, sunflowers), and built-up areas. The 2006 image has cloud cover and was excluded from the study; it comprises approximately 3.5 % of the study area. The corresponding areas for the 1989 and 1998 images were also excluded for areas of cloud cover. The overall accuracy of the 2006 land cover classification was 83 %. Land cover classification was based on the field verification in May/June/July of 2006 and 2007 and December/January of 2008.

26.2.3 Road Network Data

Road network data were obtained from three different agencies: Department of Highways, Department of Rural Roads, and Department of Environmental Quality Promotion; these were compiled into one single network. The road network dataset was geo-referenced to Landsat images with a root mean square (RMS) error <15 m. Ancillary data such as topographic maps (1:50,000 scale) and aerial photographs were used to help geo-reference the road networks. The road type used in this study was based on the classification according to the Department of Environmental Quality Promotion. The types of roads used in the study follow:

Road type 1: hard surface, two or more lanes wide (major highways, provincial highways); this type is the highest hierarchy

Road type 2: loose or light surface, two or more lanes wide (provincial highways)

Road type 3: hard surface, one lane wide (local roads)

Road type 4: loose or light surface, one lane wide (local roads); this type is the lowest hierarchy

26.2.4 Analysis

The study omitted the cart tracks in the analysis because it was difficult to geo-reference these based on Landsat images. Each road type was buffered using a Euclidean distance of 6 km. This distance was chosen because, on the basis of the previous study by Patarasuk and Binford (2012), land cover dynamics are found within 6 km of roads. Finally, land cover information was derived based on the buffered area to determine the distribution of land cover for each road type.

26.3 Results

26.3.1 General Description of Road Network

In general, roads are distributed throughout the province. Roads were most extensively developed in the northern two thirds of the province. The total road lengths from 1989 to 1998 and to 2006 were 3,347 km, 4,541 km, and 4,723 km, respectively. Hence, roads were more developed for the 1989–1998 than the 1998–2006 time periods.

Table 26.1 shows the number of roads by type described in the Sect. 26.2.3 in terms of total lengths. Road type 1, of which the majority are major highways with hard surface and two or more lanes wide, is distributed throughout the province; it accounted for 29 % of the total road lengths in 1989, 22 % in 1998, and 20 % in

Table 26.1 Total road lengths by road type

	Year 1989				Year 1998				Year 2006						
	Road type 1	Road type 2	Road type 3	Road type 4	Total 1989	Road type 1	Road type 2	Road type 3	Road type 4	Total 1998	Road type 1	Road type 2	Road type 3	Road type 4	Total 2006
Total road lengths (km)	970.75	83.47	1,371.06	922.14	3,347.42	1,006.98	115.14	1,445.79	1,973.26	4,541.16	944.54	117.82	1,471.65	2,188.97	4,722.97
Percent (%) of Total	29.00	2.49	40.96	27.55	100.00	22.17	2.54	31.84	43.45	100.00	20.00	2.49	31.16	46.35	100.00

2006. Road type 1 usually links main cities within the province as well as outside the province. For example, Highway #1 links the city of Lop Buri with Bangkok (the capital city of Thailand). Road type 2 has the least total road length in the province. This type consists of loose or light surface and is two or more lanes wide. These roads only accounted for 2–3 % of the total road lengths for the entire province. The amount of this road type was consistent throughout 1989–2006. Roads of type 2 are scattered in the northern and the eastern sections of the province. Road type 3, which classified as one lane wide with a hard surface, had the greatest total of road lengths in 1989, which proportionally accounted for 40 % of all other road types. However, the number dropped to 32 % in 1998 and remained at approximately 32 % in 2006. These roads are found mostly in the northern part of the province (i.e., north of Highway #205) (Fig. 26.1). Last, road type 4 has undergone the highest amount of development. The total road lengths accounted for approximately 28 % in 1989. The amount of roads developed was added to the total road lengths, which were 43 % in 1998 and 46 % in 2006. This type of road was mostly developed in the northern section of the province.

26.3.2 Road Type and Land Cover

The majority of the landscape in Lop Buri Province is covered by forests, water, plantation, rice paddies, upland crops, and built-up areas (Patarasuk and Binford 2012) (Fig. 26.3). Table 26.2 shows the percentage of land cover distribution within a 6-km buffer for each road type. The analysis showed that, in general, upland crops are the major land cover found along all road types. That is, upland crop cover has the highest percentage distribution within each particular road type. One exception is noted within road type 2 in 1989, where there are more forested areas than upland crops. As the year progressed, the percentage of upland crops within each road type increased. The highest increase is within road type 2 between 1989 and 1998; the percentage cover increased from 41.4 % to 56.87 %.

Forest cover is usually the second most common occurrence within the 6-km buffer of roads. Exceptions for this are within road type 2 in 1989 where it is the highest. Another exception is within road types 1 and 3, which are third highest. The results indicated that Lop Buri Province experienced forest cover decline from the 1989–1998 period to 2006. The highest amount of the forest cover decline is within the buffer of road type 2 and between 1998 and 2006 (11 % decline).

Next, rice paddy landscape fluctuates across the time period. For example, for the years 1989 and 1998, within road type 1, rice paddies have the third largest distribution, but the second largest in 2006. Across all road types, rice has the least distribution along roads of type 2 with 10.41 %, 3.73 %, and 1.60 %, respectively for 1989, 1998, and 2006. Similarly to the trend with forest cover, the analysis also revealed that the amount of rice cover within each road type had declined from 1989 to 1998 and to 2006. The biggest decline was within road type 3 in 1998 with a reduction of 7.62 %.

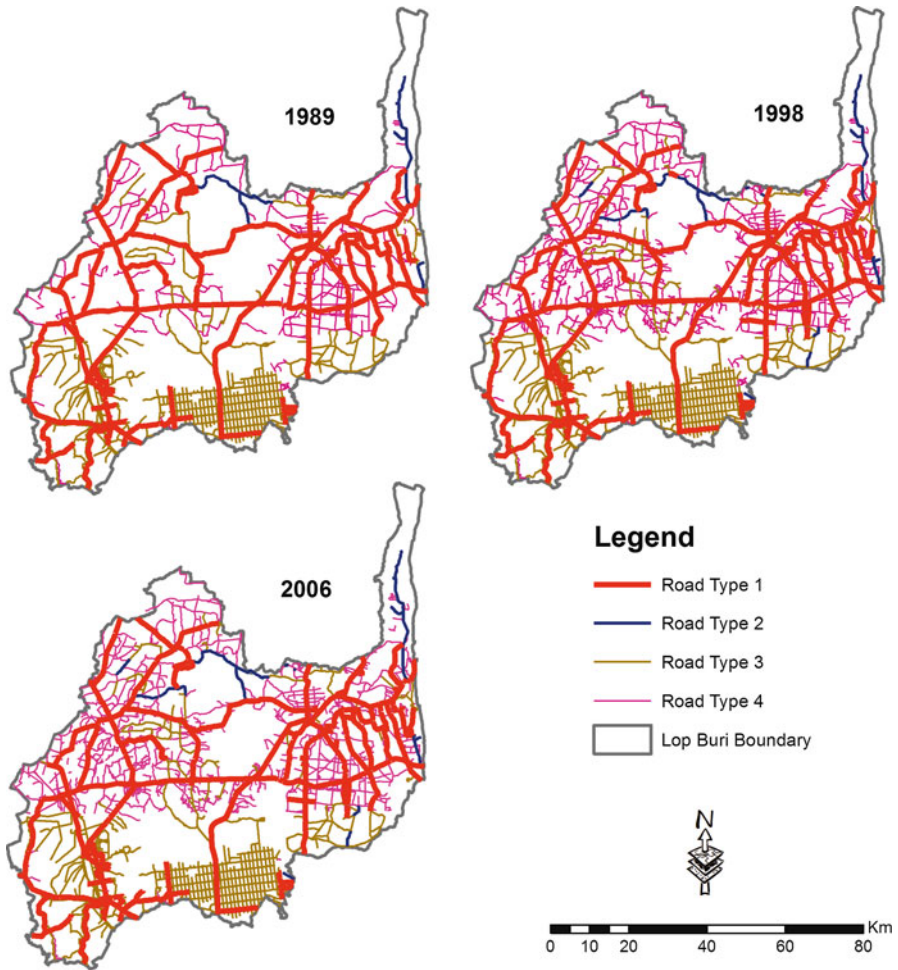


Fig. 26.2 Road network by type: type 1, hard surface, two or more lanes wide (major highways, provincial highways); type 2, loose or light surface, two or more lanes wide (provincial highways); type 3, hard surface, one lane wide (local roads); type 4, loose or light surface, one lane wide (local roads)

Plantations (teak and eucalyptus) in Lop Buri Province emerged on the landscape in 1998. However, the distribution of plantations was very small compared to other agriculture activities such as upland crops and rice. Plantations within each type of road buffer occupy less than 1 %. They are found along all road types. Note that no plantations were observed in 1989.

Water, which includes rivers, lakes, reservoirs, and ponds, contributed to less than 3 % within each buffered area. The amount of landscape covered by water has increased dramatically in 2006 because of the construction of the Pa Sak Dam/Reservoir, located in the eastern section of the province (Fig. 26.1).

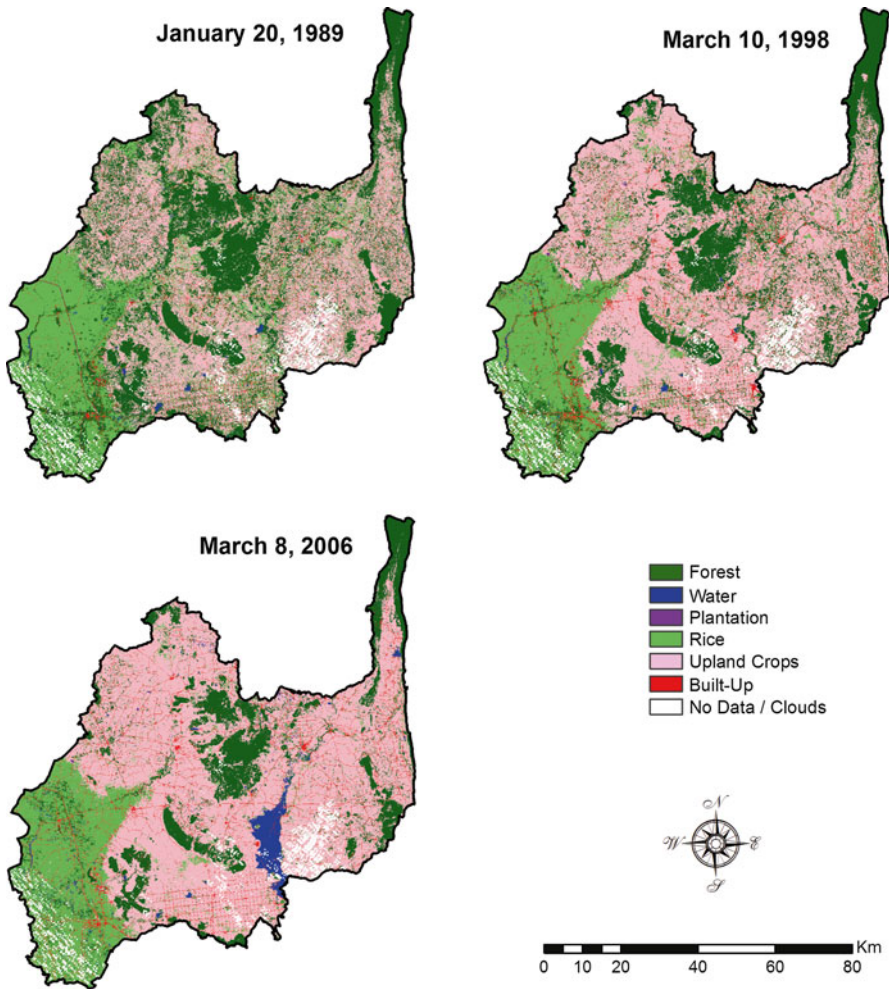


Fig. 26.3 Land cover distribution map (From Patarasuk and Binford 2012)

Last, Lop Buri Province is largely an agriculturally based economy with the majority of the landscape consisting of rice paddies and upland crop fields. Thus, only a small percentage is covered by built-up areas for human settlements. The built-up areas found within each road type are less than 7 %. The majority of built-up areas are found within the buffers of road types 1 and 3. Throughout the study time period, the amount of built-up areas has increased. The biggest increase was within road type 2 in 2006, from 4.15 % to 5.86 %.

26.4 Discussion

The results showed that agricultural activities, particularly upland crop fields, dominate the landscape. Thus, the situation in Lop Buri Province does not support the first hypothesis stated in the introduction, that built-up areas exceed agricultural areas along the highways more than along local roads. Within road types 1 and 2, rice and upland crops have contributed to more than 50 % of the landscape; built-up areas have only 3–4 % distribution. However, if compared with the built-up area land cover class, more built-up areas (by percentage) are found in road type 3 and 4 than road types 1 and 2. In contrast, the results support the second hypothesis (local roads have higher distribution of agricultural areas than built-up areas). The presence of rice paddies and upland crop fields have contributed to 50 % of the landscape along roads type 3 and 4. Last, the third hypothesis is supported as forest cover was reduced from 1989 to 2006. Within each road buffer, the amount of forest cover ranged from 30 % to 45 % in 1989; this amount decreased to 14–25 % in 2006.

The decline of forests in Lop Buri Province suggests that the land was converted to other uses within the 6-km road buffer, especially to rice and upland crops (Patarasuk and Binford 2012). More forest loss occurs adjacent to hard-surface roads (types 1 and 3) rather than loose-surface roads (types 2 and 4) when compared between highways and local roads (Table 26.2). Furthermore, rice paddies are found more often along local roads than highways, and a greater percentage of upland crops are distributed along the highway than along local roads. Highways and hard-surface roads are easily accessible all year round. They provide better travel speed, reduce travel time, and reduce travel cost in transporting agricultural products to markets (Soares-Filho et al. 2004; Verburg et al. 2004). Thus, areas along highways or hard-surface roads create more incentives for people to convert the land. An example is the National Highway No. 1, which is the main land transportation arterial between Lop Buri Province and Bangkok. Most crops grown in the province are transported to Bangkok and are exported to overseas markets such as Japan and Europe (Entwisle et al. 2008; Phantumvanit and Sathirathai 1988; Schar 2004).

Lop Buri Province is largely an agricultural area and is considered as part of Thailand's 'Rice Bowl' region (Cheyroux 2003). Rice and upland crops are largely grown in the province, and they occupy more than 50 % of the landscape. Upland crops have played an important role in the province's economy during the past several decades. They have dominated the landscape pattern by replacing forests and rice paddies (Patarasuk and Binford 2012) (Fig. 26.4). Rice paddies remain largely in the western section of the province where they are served by the irrigation systems (Figs. 26.3). Upland crops fields replaced rice paddies mostly in the upland areas, because there are no irrigation systems in the upland areas and the farmers had to rely on the availability of the rainfall (personal interview). Furthermore, the Thai government launched an agricultural diversification policy in early 1990 to encourage farmers to adopt other crops as alternatives to rice to increase their household incomes. As a result, many farmers converted rice to upland crop fields

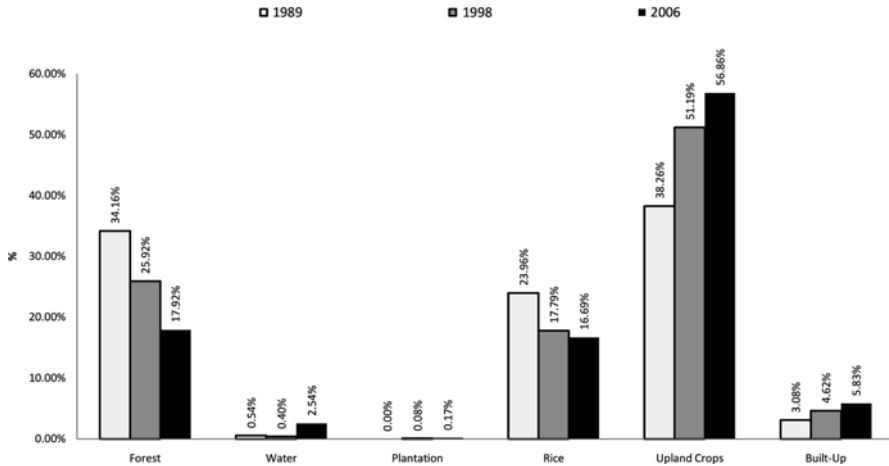


Fig. 26.4 Percentage of land cover distribution graph (From Patarasuk and Binford 2012)

(Cheyroux 2003; Schar 2004; Sirisup and Kammeier 2003). In addition, the cropping pattern has changed from rice to upland crops because of the response to demand from foreign markets, especially in Europe for the animal feeds industry (Entwisle et al. 2008; Phantumvanit and Sathirathai 1988; Schar 2004).

As roads developed, the connectivity changed. Local roads are more connected to highways, hence, improving transportation routes and access within Lop Buri Province and outside the province. The landscape pattern has also changed along all road types. Roads may have had major roles in land cover change; however, other factors can contribute to land cover change at the same time (Lambin et al. 2001), including climate pattern, household income, and population pressures (Cropper et al. 1999; Dale 1997).

This research has shown a link between land cover pattern and its distribution along different road types—hard versus loose surface and highway versus local roads—in Lop Buri Province from 1989 to 2006 by using GIS and remote sensing technology. With the development of the road network that aimed to improve social and economic development during the past two decades, the distribution of land cover along these types of roads has changed over time. Land cover change is a major contributor to local and global environmental change. The loss of forest and increase in upland crops can lead to changes in local climate and local hydrology as well as to loss of biodiversity (Dale 1997; Kummer and Turner 1994).

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