STUDY ON SPATIAL AND TEMPORAL CHANGES OF FOREST COVER DUE TO CANAL ESTABLISHMENT IN PEAT LAND AREA, CENTRAL KALIMANTAN[1]

Studi Perubahan Spasial dan Temporal Penutupan Hutan Akibat Pembangunan Kanal di Areal Lahan Gambut, Kalimantan Tengah

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ABSTRAK

Artikel ini membahas tentang dampak dari pembangunan saluran irigasi terhadap distribusi spasial hutan dan lahan terbuka di eks pengembangan lahan gambut, Kalimantan Tengah. Untuk mengetahui kondisi penutupan hutan sebelum dan sesudah pembangunan saluran, digunakan citra Landsat TM rekaman tahun 1996 (sebelum pembangunan), 1998 dan 1999 (sesudah pembangunan). Hipotesis yang digunakan adalah penurunan air tanah sebagai akibat dari pembuatan saluran telah menjadi "driving force" perusakan lahan. Indikator yang digunakan dalam penelitian ini adalah persentase distribusi lateral dari penutupan hutan serta terbukanya lahan-lahan kosong basah maupun kering di sekitar kanal.

Penelitian ini menunjukkan adanya hubungan yang sistematis antara penurunan persentase penutupan hutan dan peningkatan persentase luas lahan terbuka dengan jarak dari saluran-saluran air yang dibangun, khususnya pada areal A. B dan C dimana satuan lahannya didominasi oleh lahan gambut. Penelitian ini sekaligus menggambarkan tentang peranan GIS dalam evaluasi gejala pemicu terjadinya kerusakan lingkungan.

INTRODUCTION

In Indonesia there are roughly **16.8** million Ha of peat lands available **(RePProt, 1990** in Lembaga Penelitian IPB, **1999),** in which approximately **80%** are swampy peat forest. Of approximately *5.2* million Ha of peat land available in Kalimantan, 2.4 million Ha are located in Central Kalimantan Province. At present, almost all of the swampy forests within the production forest are exploited. Some areas were also converted into the other land use.

From **1996** up to **1998,** large scale of peat forest clearing to establish rice field in Central Kalimantan had brought either national or international attention. This "mega-rice project" was implemented through the President decree issued in **1995.** Since the beginning of **1996,** large scale of irrigation canals had been intensively built.

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1 **A part of this paper had been presented at the workshop on the study of status and distribution of peat in Indonesia organized by Wetlands International - Indonesia Programme on October 25,2002.**

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Establishment of lengthy irrigation canals had caused serious ecological destruction, such as, bio-diversity and hydrology disturbance (Fakultas Kehutanan IPB, 2000a).

At present, since the project halted in the end of 1998 during the reform era, destruction of peat forest due to illegal logging was continuously occurred. The activities that produce the most obvious changes in this fragile environment are establishment of irrigation canals and rice field. Peat land has an important role as a buffer of surrounding ecosystem that highly sensitive to the environment changes particularly due to cultivation activities. Hence, land clearing should be avoided.

Now, status of the area was officially restored from the rice field project in Central Kalimantan into its original function, namely forested area. The idea lies behind this study was to investigate peat land destruction due to natural and human-induced disturbance using satellite data. This study attempted to resolve a set of problems, including delineation of forest conservation and restoration. Within the study area, where forests have been steadily eliminated over years, the major aim is to reduce fragmentation of the forest and to identify an area to conserve forest bio-diversity. To know the presence of forest cover before the implementation of the project, derivation of forest cover before the project execution was done using satellite imagery data. With knowledge of the original forest cover of the territory, it is then possible to know the absence/presence of forest covers after the project. With this spatial information, a potential distribution of forest can be delimitated.

Some studies regarding the ex-mega rice project had been performed (Lembaga Penelitian IPB, 1999, Fakultas Kehutanan IPB 2000a and 2000b). However, most of them are focusing on sosio-economic aspect, legal aspect and capacity building within the area after the area was restored into forest territory. Lembaga Penelitian IPB (1999) recommended that the programs in blocks B, C and D should be focused on restoration of bio-physical environment in the following aspects, i.e., hidrology, land cover, land conservation and preservation, as well as community service for local people. A part of block A can be continued as the rice-field project.

To achieve the study goals, a database about territorial information system of good quality is required. The study demonstrates the utility of geographic information system (GIS) and satellite imageries for investigating the triggering phenomena of land degradation within peat land area. Now, natural and human-induced disturbances are possible to be detected through Landsat Thematic Mapper (TM) imagery. However, since the Landsat 5 TM data used in the study contain serious errors, i.e., stripping/banding, line dropout and or start line errors due to sensor-malfunction, the cover information was derived using manual interpretation. The successful use of remotely sensed data such as TM data has been well described in many literatures. These widely used to document deforestation and/or land-cover/land-use change. Numerous studies using a GIS as the essential tool for analyzing the spatial distribution of forest cover and assessing environmental condition cover can be found in Roseberry *et al* (1994), Cowen *et al.* (1995), Schuft *et al.* (1999), McCracken *et al.* (1999), Pereira *et al.* (2002), Weber and Dunno (2001), Spencer *et al.* (1997), Wu *et al.* (2002), and Felicisimo *et al.* (2002).

The study objective is to identify and quantify forest cover changes during establishment of irrigation canal for rice field that was implemented between 1996 and 1999. The specific objectives of the study are:

- ✓ To produce land cover change (historical change) particularly forest cover change in each zone between 1996 and 1998 (temporal analysis)
- ✓ To evaluate pattern of forest cover a long side the irrigation canals (spatial analysis).
- ✓ To assess the proportion of bare land enhanced due to canal establishment.

METHODS

Characteristic of the study area

The study area was originally used for limited production of fishing, hunting and extraction of non-timber product such as rattan, latex, fruit, purun (grass), rainfed paddy field low tide paddy field (handil system), grazing for water buffalo etc. Most of the study area is covered by peat land forest. The soil conditions of the study area are characterized by low porosity soils and the general lacks of relief result in poor drainage and consequently low oxygen availability (Lembaga Penelitian IPB, 1999).

In the study site, the dry season having precipitation less than 100 mm per month commonly occurred from June to July, while the wet season (precipitation larger than 200 mm per month) occurred between October to May. In 1998, when drought effect of El Nino came, there was a climate anomaly. In this year, dry months were occurred in March and April, while wet months were occurred only in October to December having total precipitation of only 2100 mm. In 1999, the precipitation in October achieved 1760 mm. Conversely, extremely high precipitation was occurred in 1999 achieving 6740 mm per year.

Study area

The study area is located in southeastern part of Central Kalimantan Province, approximately between the latitudes 2°10'00" South and 3°27'30"' South, and longitudes 113°35'00" East and 114°50'00" East. Based on the spatial measurement on the map, the total area studied is approximately 1,021,316 Ha which consisted of four blocks, i.e., block A (267,870 Ha), B (175,195 Ha), C (440,831 Ha) and D (137,420 Ha). The spatial distribution of these blocks is shown in Figure 1. It is also known that the canal length established during the project period is approximately 2,114.07 km. The average canal density is about 2,07 m/Ha, ranging from 0.79 m/Ha in block D to 5.01 m/Ha in block A. In blocks B and C, the averages of canal density are 1.67 m/Ha and 0.84 m/Ha respectively. The block borders coincide with the main rivers, coastlines and man-made streams within the area.

The dimensions of irrigation canal developed in the study area are as follows:

- First primary canal (SPI): base width 20 m, upper width 25 m, and depth 6 m,
- Main primary canal (SPU): base width 15 m, upper width 20 m, and depth 5 m,

- Secondary canal/tertiary canal: base width 10 m, upper width 15 m and depth 3 m

The canal density (canal length per unit area) was derived from division of the total length of canal by the area of interest. The canal spacing is obtained by dividing 10,000 with canal density. Hence, the canal spacing in blocks A, B, C and D are 2 km, 5.9 km, 11.9 km and 9 km, respectively.

Data

Full scene Landsat TM data of path 118-row 62 acquired in 10 May 1996, 29 March 1998 and 8 September 1999 were used. The data acquired in 1996 represent forest cover condition before the mega rice field project was implemented, while the data set acquired in 1998 and 1999 represent land cover condition after the project termination.

The supporting data include several maps such as topography, land use urban villages/hydrology (steams and rivers), canal network and reports concerning peat land development.

Study methods

In general, the study methods include several steps: (1) image-to-map rectification and image-to-image registration, (2) unsupervised classification, (3) visual interpretation and accuracy assessment, (4) theme extraction *(on screen digitizing)* and data input from hardcopy (5) spatial and tabular analyses, (6) creation of transition matrices for change detection and (7) judgment.

Classification scheme

In this study, six land cover classes in each date were established. These classes were developed in such a way that could be recognized in Landsat TM data. Descriptions of each class developed in this study are as follows:

✓ Dense secondary forest (DSF): this class includes logged over forest that had been exploited several years ago (ex-concession area, e.g. PT. Barito Utama and PT. Mengkatip). Forest covers are mostly low land forest having closed canopy ($\geq$ 70% canopy). The mean of the standing stock of this forest is approximately 168 m^3/Ha. In the study site, several commercial species found are shorea (*Shorea belangeran*), jabon (*Anthocephalus cadamba*), keruing (*Depterocarpus coriaceus*), pulai (*Alstonia scholaris*), nyatoh (*palaquium* sp.), kapur naga (*Calophyllum soulatri*). Some protected species were also found, such as jelutung (*Dyera costulata*), kempas (*Koompassia malacensis*) and gemor (*Alseodaphne umbelliftora*). Within riparian ecosystem, the species are bungur (*Lagerstroemia speciosa*), *Ficus* sp., *Pandanus tectonius*, *Dracontomelon mangiferum* and *Cerbera* sp.

✓ Medium density secondary forest/Bush (MDF): this includes bush and/or trees that mostly have tree diameter less than 20 cm. Low-density of logover or virgin forests are also included in this class. This class has crown closure ranging from open canopy (10-40%) to medium crown closure (40-69%). The standing stock of this class is less than 40 m3/Ha. In this class, some pioneer species were found, i.e., tumih

(*Combretocarpus rotundus*), mahang (*macaranga* sp.) and gelam (*Melaleuca leucadendron*).

- ✓ Shrub (SHR): this includes herbaceous vegetation along riverside and streams. The land is dominated by woody shrub (≥ 50%) with less than 10% area tree canopy cover.
- ✓ Wet barren land (WBL): this is mainly inundated areas (affected by tidal flooding). This is a land of limited vegetation that may include built-up area with underlain wet land condition. This includes new land clearing for transmigration, canal, roads and other bare land.
- ✓ Dry barren land (DBL): this class includes abandoned agriculture field with dry soil and almost has no vegetation. This class also includes ex-clear cut area, residential, roads and other bare land with dry soil condition. This areas are usually located far away from canal/river streams.
- ✓ Agriculture plantation/pasture/grass/estate (APG): this class includes grass (purun) in general, agricultural land and pastures with less than 10% area tree covers. This also includes/field crops (grass, legumes, small grains, vegetables and other crop plantation). In this study we could not reliably distinguish grassland and cropland. Riparian ecosystem areas that are located along riverside, from river-edge to approximately 5 km from the river, are initially dominated by community forest. Now, after the canal establishment, the ecosystem of riparian area is significantly changed. These areas are mainly used as irrigation paddy field, settlement, orchard and rainfed paddy field.
- ✓ Water bodies (WBD) (mostly black water lake): includes rivers, streams, lakes and unvegetated banks, which affected by flooding.

Geometric correction and image-to-image registration

Before any further analysis, the Landsat TM 1996 data were geocorrected using 1:50.000 topographic map. Thirteen GCPs then were derived providing RMS error of only 0.018 pixels. This rectified image was then used as a master image to register Landsat TM 1998 and 1999. During registering these two images, 30 GCPs for TM 1998 and 24 GCPs for TM 1999 were selected producing RMS erros of 0.515 and 0.246 pixels respectively.

Theme extraction

Several themes such as block boundaries, rivers, irrigation canals, and coastal line as well as land covers were directly extracted from the image. The block boundary theme was identified directly through *on-screen* digitizing, following river edge, man made canals (anjir) edge and coastal line. Due to the data error which have serious stripping/banding, the author then decided to derived the land cover representing land cover in each date using visual interpretation on the screen.

Field data collection

Two field checks were made to collect actual ground condition in order to obtain data for training in the classification. The first trip was done in February of 2000, then followed in June 2001.

Spatial analysis of land degradation

Since each block of the study area has its own specific characteristic and condition as well as bordered naturally by rivers, canals and coastal line, the spatial analysis was done independently in each block. The spatial analysis applied in this study included:

- ✓ Buffer establishment of irrigation canal. The buffer width created was with 300 m increments to a distance of 300 m. The buffer bands were used to define the land cover within the band distance at both sides of the canal network. Similar method also performed by Schuft *et al.* (1999).
- ✓ Overlay analysis

Change detection

Temporal analysis was done using post-classification comparison (PCC). The vector data of land/forest cover in one date was then converted into its own resolution (30 m x 30 m). These raster data were then used to establish transition matrix. Because of the difference in time between the date of TM 1998 (March) and TM 1999 (September), it is crucial to notice the rainfall effect on the land cover condition. Judicious interpretation concerning the land cover was made, since the classification was done using manual interpretation, we could not assess the accuracy of our interpretation quantitatively (we did not select any samples for accuracy assessment). However, base on ground samples collected during ground check performed in February 2000, the overall accuracy was approximately higher than 90%.

RESULT AND DISCUSSION

Land Cover Changes

The independent classification performed in this study shows substantial shift in land cover from 1996s to 1999s. In general, the project activities had caused substantial loss in forest cover, i.e., dense secondary forest (DSF) and medium density forest (MDF). To better understand the types and nature of changes occurred between 1996 and 1999, the transition matrices describing the "from-to" changes as shown in Tables 1, 2, 3 and 4 were developed. As shown, significant decline in dense secondary forest occurred in blocks A, B and C. The highest dense secondary forest decline was occurred in block C (129,929 Ha), then followed by blocks A (92,628 Ha), B (54,400.5 Ha) and D (2,485 Ha). Inversely, there were significant increases in wet barren land (WBL) in these three blocks. It is shown that the highest increase of approximately 158,000 Ha of WBL was found in block A, i.e., from 15,000 Ha to 173,000 Ha. The second largest increase in wet barren land was found in block C (151,000 Ha), i.e., from about 8,000 Ha to about 159,000 Ha, then followed by block B (66,000 Ha) from 11,000 Ha to 77,000 Ha in block B. In area of predominantly covered by peat land (blocks A, B and C), the increase in wet barren land was found to be correlated with the canal density developed in each block. In block A, the canal density is about 5 m/Ha, while in blocks C and B are 0.84 m/Ha and 0.79 m/Ha, respectively. In block D, in which the area has no very deep peat (peat depth > 3 m), although the canal density was about 2.07 m/Ha, almost no significant increase in wet barren land was found.

In block A, where the irrigation canals were intensively developed, approximately 76.5% (92,628 Ha) of dense secondary forest and 80% (35,556 Ha) of medium density forest were disappear during the project period. Table 1 shows that much of these forest classes changed into wet barren land. Of 178,729.5 Ha of wet barren land found in block A, approximately 87,684 Ha come from dense secondary forest and 23,860 Ha come from medium density forest. Shrub also changed extensively (79,6%) changed into wet barren land. Similar to block A, significant forest decline also occurred in blocks B and C. In block B, of 103,129.6 Ha of dense secondary forest originally existed in 1996, approximately 52.7% (54,400.5 Ha) had changed mostly into wet barren land. The remaining dense secondary forest areas found after the project termination was approximately 48,723 ha (27.81%) (see Table 2). As described in Table 3, the widest forest change was occurred in block C. Approximately 129,929.9 Ha (65%) of dense secondary forests and 30,886 Ha (97%) of medium density forest were disappear. Most of them were changed into wet barren land. After the irrigation canal establishment, of 440,831,3 Ha of block C, there are about 159,606 Ha wet barren land and 25,351 Ha dry barren land. In block D, where the initial land covers are dominated shrub and agricultural plantation, only small increase of barren land either wet or dry were found (see also Figure 1). As indicated in the Tables 2, 3, 4 and 5, most of the area classified as wet barren land for 1999s come from areas classified as either dense or moderately dense forest. Referring to Tables 1, 2, 3 and 5, it was noted that the changes of forest areas are ranging from 53% to 100%.

Table 1. Transition matrix of land cover changes from 1996 to 1999 in Block A

"From" land cover of 1996s	"to" land cover of 1999s							Total (ha)	Percent of change	Area of change
	D. Sec. Forest	Med. D forest	Shrub	Agric. plant.	Wet barren land	Dry barren land	Water body			
D. sec. Forest	28,475.3	3,555.8	1,423.8	-	87,648.4	-	-	121,103.4	76.5	92,628.04
Med. d. forest	3,190.4	8,852.0	6,700.5	1,110.1	23,860.5	695.0	-	44,408.4	80.1	35,556.45
Shrub	-	2,354.5	7,768.9	3,794.9	23,960.3	153.0	-	38,031.7	79.6	30,262.77
Agric. Plants	-	-	6,409.2	1,319.6	8,334.0	4,859.2	-	20,922.1	93.7	19,602.50
Wet barren land	-	-	526.4	845.7	13,848.0	-	-	15,220.1	9.0	1,372.12
Dry barren land	-	-	2,611.3	1,328.2	17,373.0	3.2	-	21,315.7	100.0	21,312.47
Water body	-	-	2,891.5	190.6	3,705.2	80.9	0.6	6,868.8	100.0	6,868.25
Total	31,665.7	14,762.3	28,331.7	8,589.1	178,729.5	5,791.4	0.6	267,870.2		

Table 2. Transition matrix of land cover changes from 1996 to 1999 in Block B

"From" land cover of 1996s	"to" land cover of 1999s								Percent of change	Area of change
	D. Sec. Forest	Med. D forest	Shrub	Agric. plant.	Wet barren land	Dry barren land	Water body	Total (ha)		
D. sec. Forest	48,729.1	5,912.6	2,103.2	565.2	45,819.5	-	-	103,129.6	52.7	54,400.5
Med. d. forest	-	4,173.1	2,494.6	2,446.2	4,865.8	-	1.9	13,981.6	70.2	9,808.5
Shrub	-	-	6,889.9	15,696.7	14,614.0	-	-	37,200.7	81.5	30,310.8
Agric. Plants	-	-	1,350.9	1,203.8	1,330.3	-	-	3,885.1	69.0	2,681.27
Wet barren land	-	-	25.1	1,508.0	9,543.0	-	-	11,076.1	13.8	1,533.13
Dry barren land	-	-	747.2	726.0	3,787.4	-	-	5,260.5	100.0	5,260.50
Water body	-	-	277.8	140.7	242.8	-	-	661.3	100.0	661.32
Total	48,729.1	10,085.6	13,888.9	22,286.6	80,202.8	-	1.9	175,194.9		

Table 3. Transition matrix of land cover changes from 1996 to 1999 in Block C

"From" land cover of 1996s	"to" land cover of 1999s								Percent of change	Area of change
	D. Sec. Forest	Med. D forest	Shrub	Agric. plants	Wet barren land	Dry barren land	Water body	Total (ha)		
D. sec. Forest	69,373.2	14,340.2	2,466.4	201.7	112,743.9	177.8	-	199,303.1	65.2	129,929.9
Med. d. forest	855.7	999.6	16,350.9	1,822.5	10,967.2	890.0	-	31,885.83	96.9	30,886.26
Shrub	-	41,991.5	55,072.2	16,197.6	23,890.2	9,682.2	5.2	146,838.8	62.5	91,766.59
Agric. Plants	-	-	2,813.1	4,414.8	2,729.2	-	-	9,957.15	55.7	5,542.31
Wet barren land	-	-	256.6	7,317.0	539.4	-	-	8,113.05	93.4	7,573.60
Dry barren land	-	-	5,747.7	13,711.4	4,632.2	14,601.2	-	38,692.53	62.3	24,091.29
Water body	-	-	-	1,937.2	4,103.6	-	-	6,040.80	100.0	6,040.80
Total	70,228.9	57,331.3	82,706.9	45,602.3	159,605.6	25,351.20	5.17	440,831.3		

Table 4. Transition matrix of land cover changes from 1996 to 1999 in Block D

"From" land cover of 1996s	"to" land cover of 1999s								Percent of change	Area of change
	D. Sec. Forest	Med. D forest	Shrub	Agric. plants	Wet barren land	Dry barren land	Water body	Total (ha)		
D. sec. Forest		829.7	-	489.0	1,166.8	-	-	2,485.4	100.0	2,485.44
Med. d. forest		2,031.2	354.5	407.6	432.6	4.0	-	3,229.83	37.1	1,198.68
Shrub		11,011.2	19,522.9	22,186.9	6,788.5	217.4	-	59,726.9	67.3	40,203.99
Agric. Plants		-	8,611.3	31,580.6	2,029.0	-	-	42,220.9	25.2	10,640.34
Dry barren land		-	4,674.7	11,059.7	4,294.8	758.1	-	20,787.3	79.3	16,492.46
Water body		-	3,213.6	1,714.7	4,040.9	-	-	8,969.3	100.0	8,969.31
Total		13,872.1	36,377.1	67,438.5	18,752.67	979.41	-	137,419.7		-

As shown spatially in Figure 1, tremendous forest changes are especially occurred in blocks A, B and C. Large scale of forest cover available in 1996 (before the project implementation) had disappeared in 1999 (after the project termination). Figures 1a expresses initial land covers condition before the canal establishment. The canal theme overlaid in Figure 4a is intended to show that both the first (SPI) and main primary canals (SPU) were mostly passing through dense secondary forest. In Figure 1b, it is shown that the land cover condition after the canal establishment. As displayed in Figure 1b, the barren lands are commonly found along side irrigation canal that built during the project implementation. The underlying land units of these forest covers are mostly very deep peats particularly for blocks A, B and C. This information was derived using TM 1998 and 1999. In comparison with the initial land cover condition, the forest covers are drastically disappear while barren land considerably increased. An example of forest that is more detailed and barren land distribution within the canal network is depicted in Figure 2.

Lembaga Penelitian IPB (1999) mentioned that mismanagement of peat forest such as drainage canal establishment, mining and combustion may enhance the subsidence rate due to excessive overdrained and the loss of peat layers. Since, peat environment is irreversible, the subsidence may create new water body's ("giant lakes") during the wet seasons, and dessert in the dry season. Although, the peat forest exploitation had been introduced for more than 2 decades, up to the present, there is no well-established silviculture system known. Forest degradation continuously occurred due to over cutting and almost no rehabilitation action. Illegal cutting and land conversion are also triggering the peat land forest degradation.

Land degradation at lateral dimension of the canal network

As the study objective outlined in this study, an important issues that could be addressed was to investigate the relationship between the proportion of area covered by forest and distance from the irrigation canal network. Because large portions of the study area are peat lands, we were also interested in determining the proximity of wet barren land and dry barren land to the canal network.

In the study area, the canals were initially designed to be irrigation canal. However, due to land characteristic where the land units are dominated by peat land, the canal function was altered to be drainage canal. During the field check in the first and main primary canals, it was found that the canal water flow is from the canal to inlet (not to outlet) water control. It is well known that peat area is an effective catchment area. When the peat land done is cut off through canal development, their function might be disturbed.

In this study, the 1996, 1998 and 1999 TM imageries were used to determine the relationship between the irrigation canal development and forest decline, particularly within peat land area. As shown in Figure 2, it was found that most of the forest areas (dense secondary forest and medium density forest) before the project implementation were captured within buffer <1500 m of irrigation canal. Figure 2 is intended to describe the proportion of the area covered by forest and barren land. These figures reflect the nature of the forest cover and barren land to the distance from the canal, where the barren lands are predominant near the canal network. In block A, prior to project implementation, prominent forest covers were found within buffer of less than 1500 m. The figure also shown that, the largest areas were located within buffer of less than 300 m. Since the canal density developed in block A is relatively higher than the other blocks (5 m/Ha), the most land covers were found within buffer of less than 1500 m. This is understandable because the canal network spacing is about 2 km. After the project was implemented (irrigation canal development), the substantial increase of wet barren land was found within the buffer of less than 300 m replacing the forest covers. It is interesting to note that the decline of forest area was followed by the significant increase of barren land. It is clearly shown in Figures 2a, b and c that the highest in wet barren land was occurred in the nearest distance from the canal network. In block A, about 81% of land cover within buffer 1 (0-300 m) of canal network is wet barren land, but decrease to about 74% within buffer 2 (300-600 m). The percent of wet barren land decline continuously to only 37% at buffer 10 (2700-3000 m) from the canal network. In this block, the percent of forest of dense secondary forest surpasses the percent of wet barren land at a distance between 2700 m to 3000 m from the canal (buffer 10). Similar patterns were also found in blocks B and C, but the percent of wet barren land always exceeds the percent of dense secondary forest at all buffer distances.