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ANALYSIS ON CURVE NUMBER, LAND USE AND LAND COVER CHANGES IN THE JOBARU RIVER BASIN, JAPAN

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ABSTRACT

The curve number (CN) is a hydrologic parameter used to describe the storm water runoff potential for drainage area, and it is a function of land use, soil type, and soil moisture. Therefore, the land use and land cover changes can be represented by this parameter. To simulate the Rainfall-runoff process due to the land use change, some models need CN as data input. This study describes how to estimate the CN due to land use and land cover changes in Jobaru River basin. We applied the ArcGIS tool to delineate river basin and sub-basin, and HEC-GeoHMS tool for estimating the CN. The result shows that from 1948 to 2005 the CN of the Jobaru River basin decreased from 53.29 to 52.03, which indicates that the land use changes in Jobaru River basin makes the land capability for reducing flood becomes better during this period. However, in the sub-basin the result is different. In mountainous sub-basin, the CN also decreased from 48.24 to 46.07 but in plain sub-basin the CN increased from 68.81 to 70.41. This indicates that the land capability to reduce food changes better in mountainous sub-basin but become worse in the plain sub-basin. Finally the result of CN can be utilized for flood analyzing.

Keywords: curve number, land use change, Jobaru river basin.

1. INTRODUCTION

Land use change is one of the main boundary conditions which influence many hydrologic processes. The effect of land use changes on river flow is one of the most important environmental problems of our time. Expanding cities due to economic growth, population growth or both often come at the expense of increased risk of flooding and decreased water quality and quantity. Since the 20th century, the frequency of global flood disaster has been higher than any other centuries before; one of the main reasons for this is because of land use changed by human activities. Land use changes can be represented in CN. To simulate the rainfall-runoff process due to the land use change in river basin, some models, for example MIKE 11-UHM, need CN as data input.

The CN is a hydrologic parameter used to describe the storm water runoff potential for drainage area. In calculating the quantity of runoff from a drainage basin, the CN is used determine the amount of precipitation excess that results from a rainfall event over the basin. The greater the value of CN means the greater the amount of rainfall becomes runoff. This methodology is a standard hydrologic analysis technique that has been applied in a variety of different settings throughout the United States, and the development and application of the CN is well documented. The CN is a function of land use, soil type, and soil moisture.

Jobaru River basin is one of the most important rivers in Saga Prefecture. During 1948 to 2005, due to the increasing needs of residential area, the Jobaru River basin has been affected by the changes in land use and land cover; especially the decreasing number of paddy fields and the increasing number of urban or built-up land. Several cases had been recorded that there has been major flooding which resulted in loss and damage to the Jobaru River. It was believed that one of the major causes were due to the changes in land use. Jobaru River basin can be grouped into two sub-basins; Jobaru mountainous sub-basin and plains sub-basin. Both parts have very different topography and land use. Data from 1948 to 2005 showed that the land use has changed in Jobaru River basin. For example, paddy fields tended to turn into urban or built-up land in plain sub-basin while barren turned to forest in mountainous sub-basin. The changes in land use in both sub-basins would give a different effect. Changes from paddy fields to urban areas in the plains sub-basin will likely continue. It is feared that is will affect the flow of the Jobaru River.

Previous study (H. Matsui, 2008) saw the effect of changing land use on the entire Jobaru River basin, but did not determine the influence of each sub-basin.

From this background, it is important to examine the CN due to land use changes not only in mountainous but also in plains sub-basin which can be further utilized to analyze floods.

2. MATERIALS AND METHODS

(a) The study area

Jobaru River basin is located in one of the main islands of Japan called Kyushu. It is in Saga Prefecture (Figure-1). Jobaru River is one of the Chikugo River tributaries. Originates in Sefuri Mountain and flowing to the south east to join the Chikugo River and pour to the Ariake Sea. The geographical position is approximately between 129.9 to 131.0 degrees east and 33.08 to 33.58 degrees north. The area of the basin is 72.8 km^2 and the length of the main channel is 31.9 km. Average annual precipitation is 2266 mm.

The water resources of the basin are heavily developed for irrigation, fire protection, maintaining the environment and waterways. There are a number of irrigation schemes supplying water to paddy fields. Jobaru River basin has a varied natural environment. In the middle and lower basins there are a wide variety of plants and animals living there; the upper part contains flora and fauna; the middle part has plants and animals; and down streams; there are flora and fauna. Floods are normally experienced during the rainy season which has more intense rainfall caused by typhoons. The maximum discharge recorded from 1948 to 2005 was 690m^3/s occurred in rainy season of 1953. Between 1948 and 2005, there were several floods in Jobaru River that caused damages. The discharge was recorded at Hideki Bridge point, from Hideki Bridge Observatory Station.

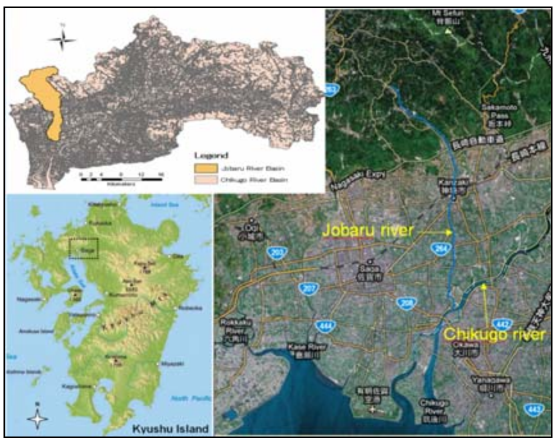

Figure-1. Study area.

(b) Data sources

In this section the details of required data are explained. They are used to estimate CN on land use and land cover change at Jobaru River basin. Digital elevation model (DEM) was provided by Japan digital map 50m grid (Elevation), 1997. The available land use data is the Chikugo Watershed land use obtained from Ryuiki Shizen Kankyou Chousa Sagyou, for the years of 1948, 1975 and 2005. Soil data was derived from Geological map of Japan (AIST-2003), Soil regions map of Japan based on reclassification, and Digital soil map of the world (FAO).

(c) River basin delineation

The first step in this analysis is to delineate the Jobaru River basin and sub-basin (Figure-2) using the HEC-GeoHMS. Data needed in this step is DEM data. Jobaru River basin outlet is determined in the downstream near the meeting point with Chikugo River, while mountainous sub-basin outlet is determined in Niiyama. The basin and sub-basin characteristics are shown in Table-1.

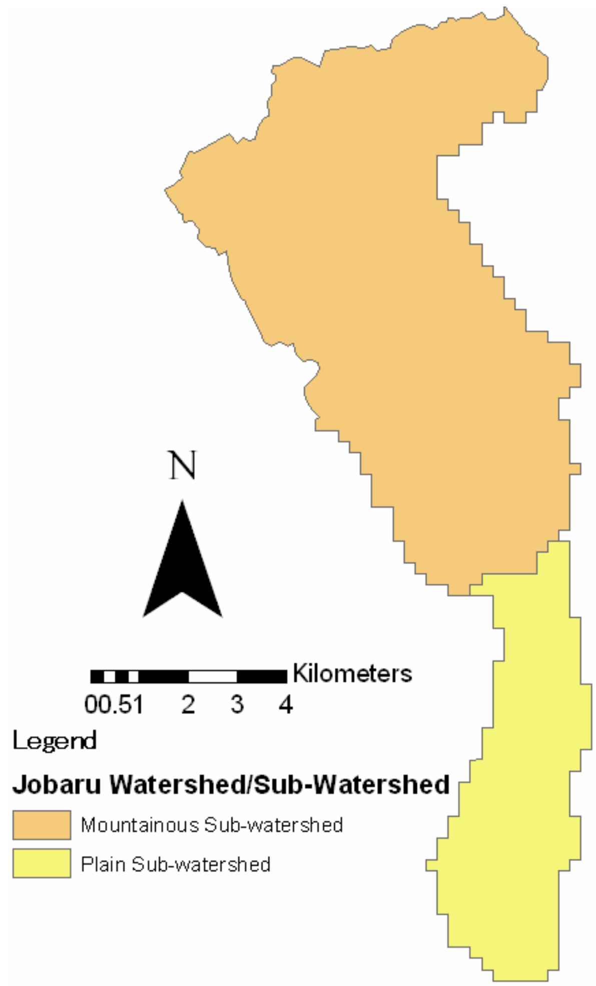

Figure-2. Jobaru basin and sub-basin.

Table-1. Basin/sub-basin characteristics.

	Plain sub-basin	Mount sub-basin	Jobaru basin
Area (km^2)	23.15	51.05	74.2
Length of main channel (km)	11.4	20.5	31.9

(d) Land use analysis

The next step is to define the Jobaru River basin land use map by intersecting the Jobaru basin map with the land use map. The original land use of Jobaru River basin in 1948 is divided into 18 classes, whereas in 1975 and 2005 are divided into 20 classes. For the purpose of flood analysis, it is necessary to reclassify the land use categories. Land use such as urban, housing, public facilities, schools can be considered the same and can be grouped into one group and classified into urban or built-up land, as well as rivers, lakes, ponds and swamps can be grouped into another, that is classified into water. The Jobaru River basin is reclassified into 11 classes as shown

VOL. 7, NO. 7, JULY 2012 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

in Table-2. Using ArcGIS tool a reclassification map for the Jobaru River basin and sub-basin land use is defined (Figure-3). The land use change is analyzed between 1948, 1975 and 2005 by using ArcGIS tools.

Table-2. Land use reclassification.

Code	Land use description
1	Water
2	Urban or built-up land
	Forest
3	Broadleaf forest
4	Coniferous forest
5	Bamboo forest
6	Mixture forest
	Agricultural land
7	Paddy field
8	Other agricultural
9	Pasture
10	Barren
11	Others

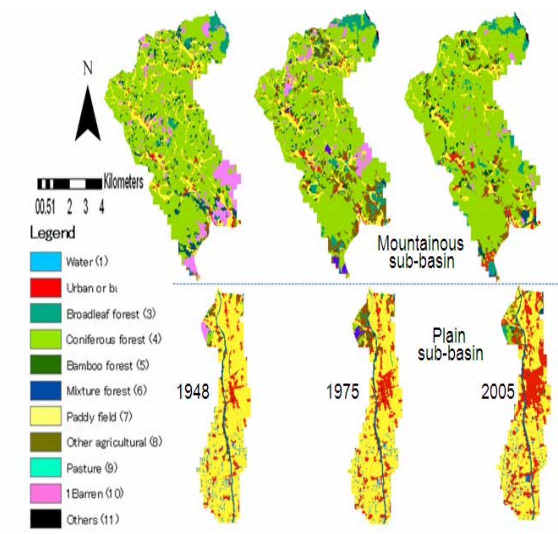

Figure-3. Jobaru river basin and sub-basin.

(e) Soil type analysis

The next step is to analyze the type of soil. The soil data from Geological map of Japan (AIST) was analyzed by using ArcGIS to obtain the Jobaru soil map, and then it is compared with the soil map of Japan based on reclassification and also digital soil map of the world to obtain the soil types at Jobaru River basin. From this analysis, it obtained that there are three soil types: Fluvic soils, Brown forest soils and Red-yellow soils (Figure-4).

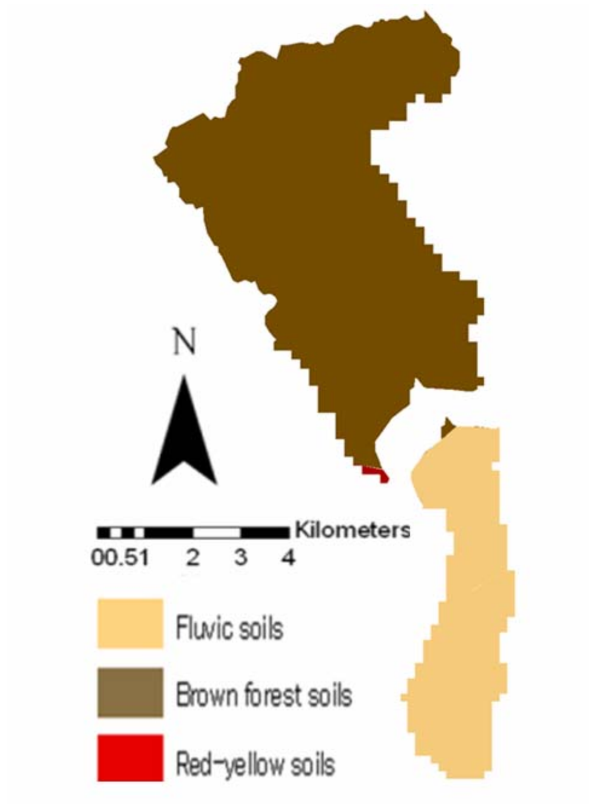

Figure-4. Jobaru River basin soil type.

(f) Curve number (CN) analysis

The next step is to analyze the CN. The CN is estimated for a drainage basin using a combination of river basin DEM, land use, soil and Antecedent Soil Moisture Condition (AMC). The CN generator requires three shape files (Figure-5): (1) the drainage basin boundaries for which CN will be calculated, (2) the soil type map, and (3) the land use map. The information needed to determine a CN is the hydrologic soil group (HSG), which indicates the amount of infiltration the soil will allow. There are four hydrologic soil groups (USDA, 1986): **A:** soil having high infiltration rates, **B:** soils having moderate infiltration rates, **C:** soils having slow infiltration rates, and **D:** soils having very slow infiltration rates. The hydrologic soil group of Jobaru River basin corresponds to the soil class that was obtained as shown in Table-3.

Table-3. HSG of jobaru river basin.

Soil class	HSG
Fluvic soils	A
Brown forest soils	A
Red-Yellow soils	C

Standard Soil Conservation Service (SCS) curve numbers are assigned for each possible land use-soil group combination. Table-4 presents the typical land use categories used for hydrologic analysis, along with

ARPN Journal of Engineering and Applied Sciences

corresponding curve numbers for each land use-soil group combination.

Table-4. Land use categories and associated CN.

Land use	Curve number by hydrologic soil			
	A	**B**	**C**	**D**
Water	100	100	100	100
Urban	77	85	90	92
Broadleaf forest	36	60	73	79
Coniferous forest	40	66	77	85
Bamboo forest	40	66	77	85
Mixture forest	38	63	75	82
Paddy field	67	78	85	89
Other agricultural land	67	78	85	89
Pasture	39	61	74	80
Barren	68	79	86	89
Others	98	98	98	98

The AMC is defined as the initial moisture condition of the soil prior to the storm event of interest. SCS methodology expresses this parameter as an index based on seasonal limits for the total 5-day antecedent rainfall (McCuen, 1982), as follows: AMC I conditions represent dry soil with a dormant season rainfall (5-day) of less than 0.5 inches and a growing season rainfall (5-day) of less than 1.4 inches. AMC II conditions represent average soil moisture conditions with dormant season rainfall averaging from 0.5 to 1.1 inches and growing season rainfall from 1.4 to 2.1 inches, and AMC III conditions represent saturated soil with dormant season rainfall of over 1.1 inches and growing season rainfall over 2.1 inches. In general, CN are calculated for AMC II, then adjusted up to simulate AMC III or down to simulate AMC I. The CN shown in Table-4 corresponds to AMC II. Once the data has been gathered, the typical process for estimating the CN for a drainage area is as follows:

(a) Define and map the boundaries of the drainage basin(s) for which CN(s) will be calculated. (b) Determine the area of the drainage basin(s). Map the soil types and land use for the drainage basin(s) of interest. (c) Convert the soil types to hydrologic soil groups. (d) Overlay the land use and hydrologic soil group maps, identify each unique land use-soil group polygon, and determine the area of each polygon. (e) Assign a CN to each unique polygon, based on SCS curve number tables (Table-4). (f) Overlay the drainage basin map on the land use-soil group polygons. (g) Calculate the CN for each drainage basin by area-weighting the land use-soil group polygons within the drainage basin boundaries. The basic equation for CN calculation is:

$$CN_{aw} = \frac{\sum_{i=1}^{n}(CN_i \times A_i)}{\sum_{i=1}^{n} A_i} \quad \text{.......................................(1)}$$

Where CN_{aw} is the area-weighted CN for the drainage basin, CN_i and A_i are CN and area, respectively for each land use-soil group polygon, and n is the number of polygons in each drainage basin.

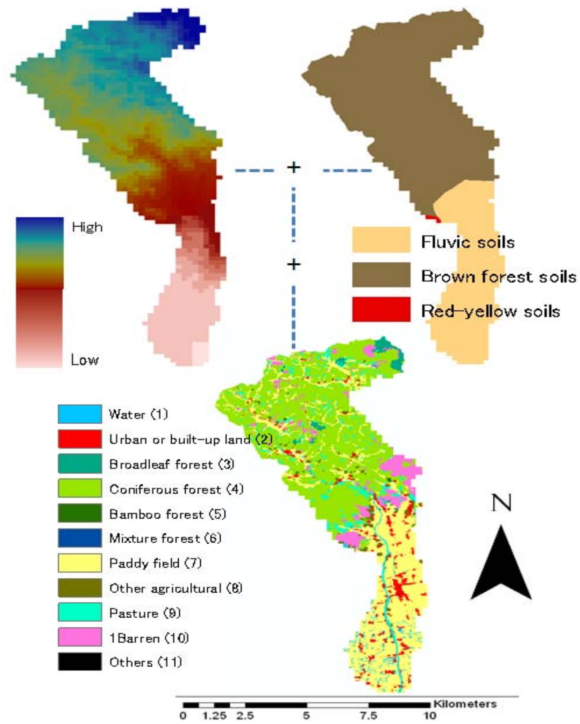

Figure-5. Three data-sets for generating CN.

3. RESULTS AND DISCUSIONS

(1) Land use change

a) Jobaru River basin

According to the analysis, in Jobaru River basin, land use changes significantly in urban area, forestry, agricultural land and barren area, while water and others remained relatively unchanged (Figure-6). The result of land use changes in 1948, 1975 and 2005 showed that the barren area tended to turn into a forest. After World War II, Japan consumes a lot of wood to build houses, many trees were cut down to be used as construction materials, so many of that forest areas turned barren. This resulted in land use in 1948. Forest area is relatively small and barren area is relatively large compared to the year 1975 and 2005. The land use in 1975 showed that barren area decreased, turning into forest. The results indicates that there is no longer booming demand for wood for construction materials at that time, reforestation were even made in barren areas, so it turns barren areas into forests

ARPN Journal of Engineering and Applied Sciences

and the same thing happened to the land use in 2005. On the other hand, the result of land use changes in 1948, 1975 and 2005 showed that the paddy fields tended to turn into a built-up land. This is due to the increased demand of land for residential. Getting land in urban areas becomes difficult and costly so that it forces the expansion into the countryside. One of the options is a paddy field. Paddy field is chosen because this area is still relatively close to urban area with flat terrain, and usually already have small group of housing. Changes from barren into forest will lead to an increase land capability in reducing flooding. The increasing of forest is predominantly caused by changes in barren into forest. Currently almost all of barren area has been turned into a forest, so the possibility of increasing forests in the future is extremely small. On the other hand, the need for residential area will increase continuously; therefore the tendency of changes in paddy fields into residential area will be very substantial later. The changes from paddy fields into residential area resulted in the decrease of land capability of reducing flooding. If these land use changes continue to happen, then it is feared that the peak flow in the Jobaru River will also continue to increase.

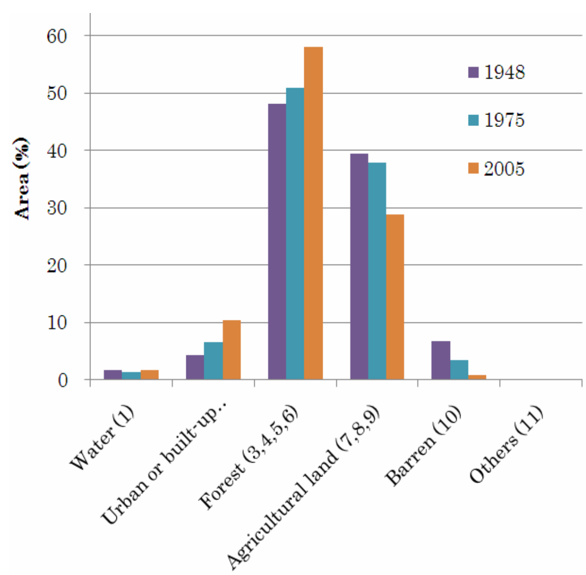

Figure-6. Land use change on Jobaru River basin.

b) Jobaru Mountainous sub-basin

In mountainous sub-basin, the land use has changed significantly in forest, barren area, agricultural land, and urban area, while water and others remained relatively unchanged (Figure-7). Dominantly, barren area turns into forest.

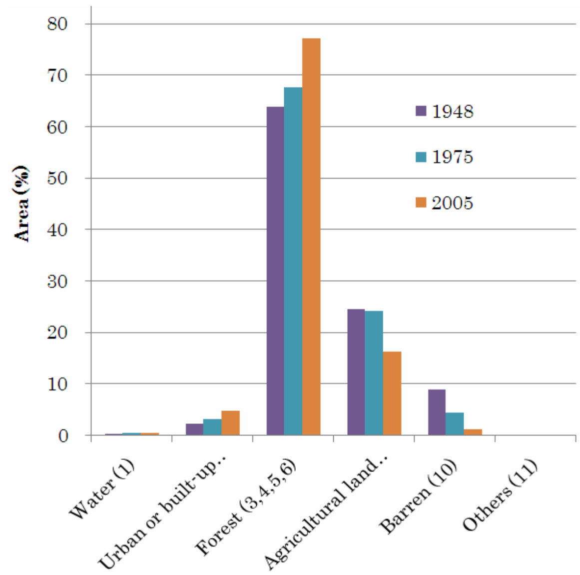

Figure-7. Land use change on Jobaru mountainous sub-basin.

c) Jobaru plain sub-basin

The land use has changed significantly in urban and agricultural land, while water, forest, barren area and others are relatively unchanged in Jobaru plain sub-basin (Figure-8). Dominantly, the agricultural land turns into urban areas.

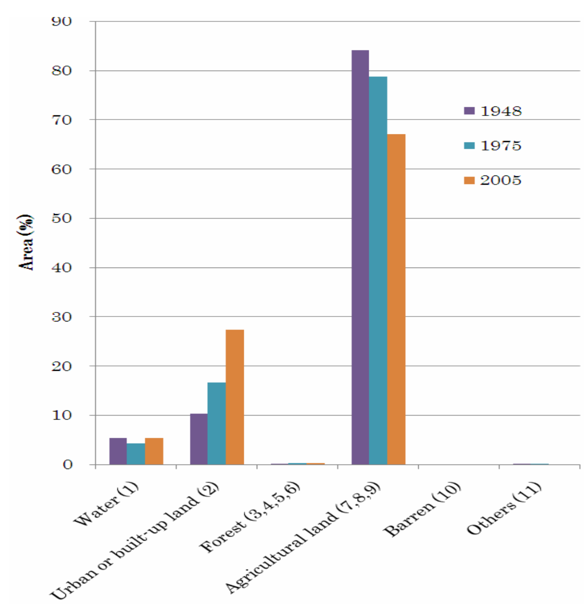

Figure-8. Land use change on Jobaru plain sub-basin.

(2) Jobaru River basin curve number

From the CN analysis, it indicated that the Jobaru mountainous and plain sub-basin has many unique polygons (Table-5).

VOL. 7, NO. 7, JULY 2012 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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Table-5. Amount of unique polygon.

Sub-basin	Unique polygon, year		
	1948	1975	2005
Mountainous	1314	1581	1019
Plain	896	886	1013

Each polygon representing one of the catchment areas and the area-weighted curve number. Each CN is representing a unique sub-basin, soil, land use and topography, therefore the average CN of the basin and sub-basin can be defined. The average CN of each basin and sub-basin are shown in Table-6.

Table-6. Average CN.

River basin/ sub-basin	Average CN		
	1948	**1975**	**2005**
Jobaru	53.29	53.54	52.03
Mountainous	48.24	48.43	46.07
Plain	68.81	69.04	70.41

The average CN of Jobaru River basin has decreased from 53.29 in 1948 to 52.03 in 2005. In this period, the main land use changes are due to an increasing of urban area and forest, while agricultural land and barren decreased. The increases in forestry were caused by changes from barren area turning into forest, while the decreasing of agricultural land was due to the increasing of the residential area. The increasing of urban area and the decreasing of agricultural land caused the increasing of CN, on the other hand, the increasing of forest and the decreasing of barren area caused the decreasing of CN. This shows that in this period the entire Jobaru River basin was changed from barren area to forest was more dominant then the changes in agricultural land to urban area. The decreasing of CN indicates that the potential storm water runoff decreased while the increasing of CN means that the potential storm runoff increased so in Jobaru River basin, the potential storm runoff decreased from 1948 to 2005. In each sub-basin, the changes in the average CN are different. In Jobaru mountainous sub-basin, the average CN decreased from 48.24 in 1948 to 46.07 in 2005. This is because in mountainous area the land use and land cover were predominantly forest, and also most of the barren area were there. In this period almost all barren area turned into forest, so it causes the CN in mountainous area to decrease. However in Jobaru plain sub-basin, the average CN increased from 68.81 in 1948 to 70.41 in 2005. This is because in that area, the dominant land use and land cover were agricultural land used especially for paddy field and residential area. In this period, a lot of agricultural land changed into residential area, and caused the increase of CN in plain area. From 1948 to 2005, the land use quality in all of the Jobaru River basin changed for the better, but if we considered the sub-basin, it shows that in the plain sub-basin, the land use quality changes was worse. For anticipating the flood in Jobaru River due to the land use change it is better to consider the sub basins, especially in the plain sub-basin. Currently, almost all barren area have already changed into forest, so the tendency of increasing forestry is limited but the demand for residential area are increasing, therefore the tendency of decreasing agricultural land and increasing urban area becomes a larger problem in the future.

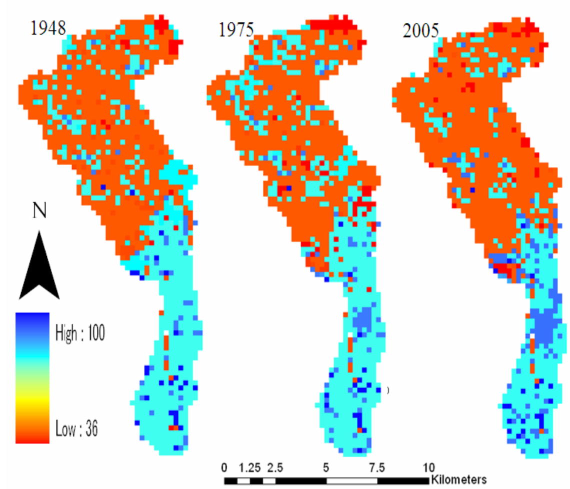

Figure-9. CN grid.

4. CONCLUSIONS

a) Land use changes during 1948, 1975 and 2005 in Jobaru River basin; urban area and forestry increased, agricultural land and barren area decreased, while water and others remained relatively unchanged. In mountainous sub-basin; urban area and forestry increased, agricultural land and barren area decreased, and water and others remained relatively unchanged. In plain sub-basin; urban area increased, agricultural land decreased, while water, forest, barren and others remained relatively unchanged;
b) The increase in forest is predominantly caused by changes in barren into forest, while the decreasing of agricultural land this is due to the increased demand of land for residential;
c) The changes of the land use can be represented by the changes of the CN;
d) In the Jobaru River basin the average CN has decreased. In the mountainous sub-basin, the average CN also has decreased but in the plain sub-basin, the average CN has increased; and
e) The result of the CN change can be finally utilized to analyze floods.

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