EFFECTS OF THE UPPER WATERSHED LAND COVER CHANGES ON THE FLOOD REGIME OF THE RIVER BASIN IN TANAY, RIZAL, PHILIPPINES

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ABSTRACT

Flood and land cover change analyses were used to assess the dynamics of flood in the floodplains of Tanay River. Flood simulation was carried out using the derived hydrograph under different land cover scenarios to analyze the effects of land cover changes on the flood regime of the river basin in Tanay, Rizal. The model was calibrated using the measured water depths and discharge of the river cross-section. Land cover analysis revealed that the watershed is predominantly covered by orchard plants and grasses with an approximate area of about 2286.68 and 1157.4 ha, respectively. Reforestation of the grasslands in the upper portion of the watershed can considerably reduce the volume of floodwater in the floodplains of the river. Flood simulation using the land cover of the area predicted the flood depths and delineated the spatial extent of flooding in the floodplains of the river. The total area that may be saved from flooding if the grasslands in the upper watershed are reforested is about 16.4 ha. About 12.4 ha is located in Barangay Plaza Aldea. The two major environmental adaptive measures that need to be done are the development of a comprehensive community-based rehabilitation and management of Tanay watershed and the protection of the remaining watershed of the area.

Keywords: flood mapping, hydrograph, land cover analysis

1 RATIONALE

The magnitude and frequency of flood disaster during the last century is generally higher than any time before. Numerous disastrous flooding had taken place in many parts of the world during this period. Great floods were the most common type of geophysical disasters in the late half of the twentieth century (Razi et. al. 2010).

Many developing and developed countries have suffered financially due to the impacts caused by flooding. In September 2011 heavy rainfall led to the submergence of low-lying areas in Pampanga and Bulacan in the Philippines. The estimated damage based on the report of the National Disaster Risk Reduction and Management Council (NDRRMC) was about 9 billion pesos while the affected population, mostly in flood-hit areas in Bulacan and Pampanga, is more than 2.7 million people.

The unprecedented increase in human population will further cause stress on the land to support the demand for food and fiber. This pressure on the environment creates a multitude of effects on the ecosystem particularly on biodiversity, as well as on the water hydrology of a watershed.

The stress caused by these factors generates a continuum within a landscape. Changes on the land cover upstream of a landscape may also change the hydrologic regime in the area and may cause negative impact downstream of the landscape.

Vegetation plays an important role in infiltration and can slow the movement of runoff, allowing more time for it to seep into the ground. The surface soil layer in a forest or a pasture will generally have greater infiltration capacity than a compacted soil surface (Giertz et. al. 2006). Several studies reported that changes in land cover from woodland to agricultural land lowers infiltration rate (Giertz et. al. 2006).

Quantification and prediction of the effects of land cover changes on the dynamics of flood is helpful in risk reduction and environmental management. It likewise helps in identifying areas that needs to be preserved and areas that must be given due attention to increase its land cover.

In order to help mitigate the impact of flooding in the low-lying areas of the town, a study was conducted to analyze the effects of land cover changes on the flood regime of the river basin in Tanay, Rizal.

2 CONCEPTUAL FRAMEWORK OF THE STUDY

A governing principle of flood management has established that changes in land cover result in commensurate changes in hydrologic response. Rainfall-runoff relationships within a particular landscape are the result of the interplay of many factors, but are governed mostly by the interaction of climate, land cover, and soils (Hernandez 2000).

Land cover assessment can be satisfactorily accomplished with the aid of satellite image and other thematic maps of an area. The spatial extent of flood event can be predicted using the hydrologic and geometric data of a river. Such factors were combined together to create a decision tool that helps understand the interaction of a flood event and the condition of its land cover (Figure 1).

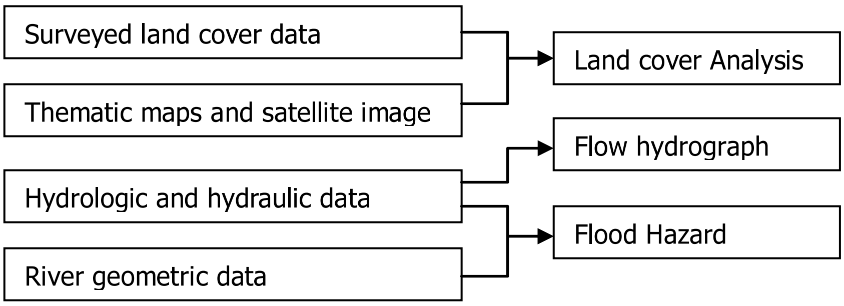

Figure 1: Conceptual framework of the study

3 METHODOLOGY

a. Land cover assessment

The land cover of the study area was derived using the latest land satellite image (Cateye 2012) and other thematic maps of the area using unsupervised classification tool of the IDRISI software. Ground truthing was undertaken to ensure the accuracy of the land cover that was generated.

b. Identification of the priority areas for rehabilitation and reforestation

The areas that can be subjected for reforestation was determined based on their present land use and their potential as reforestation area.

c. Peak flow hydrograph simulation

The peak flow was simulated using HEC-HMS software (Figure 2).The input parameters were

the thematic maps such as Digital Elevation Model (DEM), soil type map and the created land cover scenario of the watershed.
The February 22 thunderstorm with a total rainfall of 80 mm and the rainfall data of 418 mm during the Typhoon Ketsana (Ondoy) served as the meteorologic input of the model.

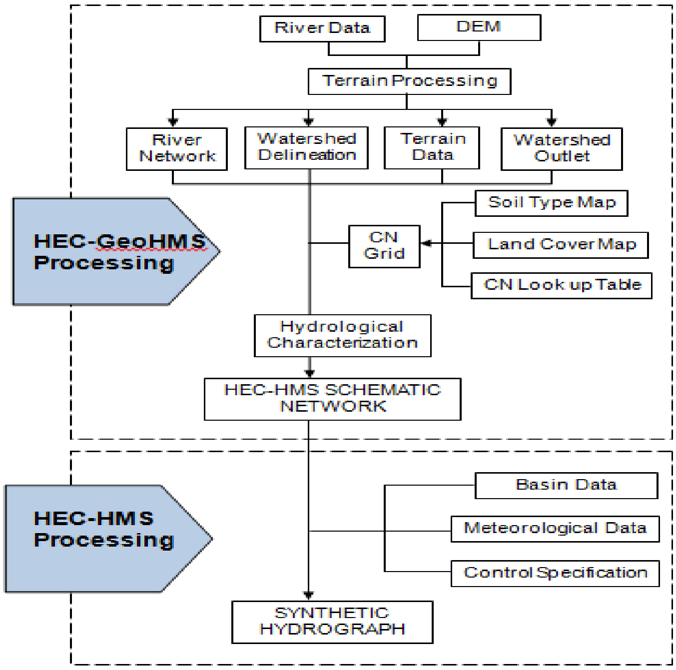

Figure 2: Flowchart for the synthetic hydrograph modelling (Maidment 2002)

Model Calibration

Calibration is a process of standardizing predicted values, using deviations from observed values for a particular area to derive correction factors that can be applied to generate predicted values that are consistent with the observed values. Every hydrologic model should be tested against observed data to understand the level of its reliability (Linsley 1982; Melching 1995).

The model was calibrated using the measured river water elevation during the February 22, 2013 thunderstorm and the calculated discharge of the river at a pre-selected location. The simulated water elevation and peak discharge were compared with the measured water elevation and the computed discharge of the river cross-section.

d. Flood modelling and assessment

The HEC-RAS (Figure 3) was used to simulate the water elevation during a storm event using physiographic factors like size, shape, slope, type of river embankment, and the simulated hydrograph of the river.

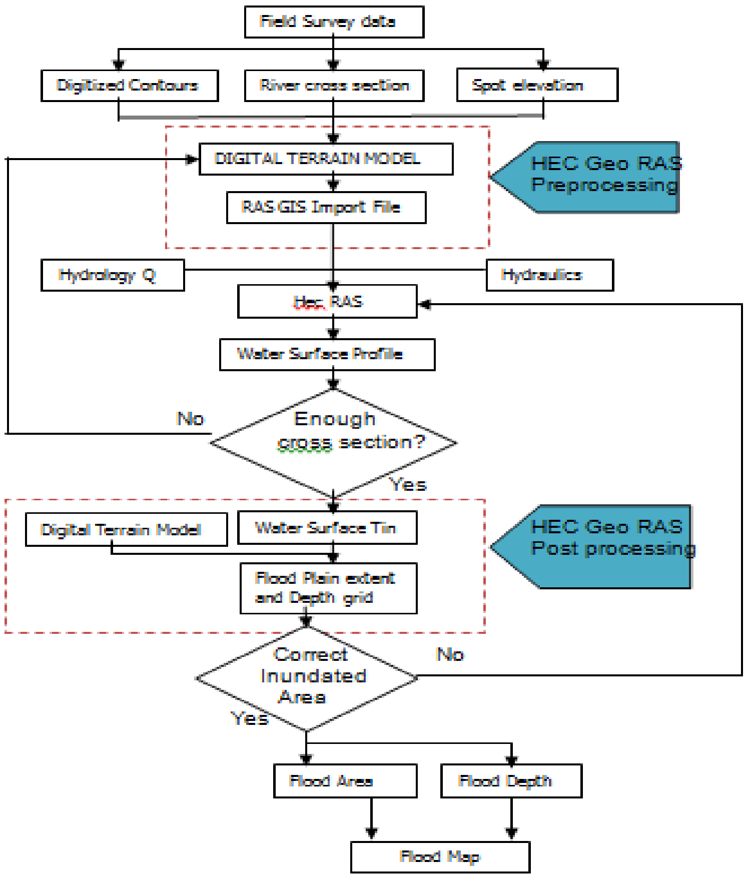

Figure 3: Flood mapping using HEC-RAS and HEC-GeoRAS (Maidment 2002)

A flood hazard map was generated using the simulated water elevation. It was classified according to its potential to flooding. The classifications along with their corresponding depth are as follows:

- Low 0.20 to 0.59m
- Moderate 0.60 to 1.49m
- Extreme 1.50 to 3.5m
- Very Extreme 3.55 and above

4 RESULTS AND DISCUSSION

Present Land Cover of the Area

The dominant land cover of the watershed is the orchard agro-ecosystem (Figure 4).The plants that are commonly grown are mango, banana, coconut and other fruit bearing trees. It has a total area of about 2286.68 ha. Grassland is next to orchard with a total area of about 1157.40 ha. The agricultural production areas which are mostly planted with rice, corn, vegetables and root crops such as cassava are about 230.02 ha. The residential areas are the lowest with an approximate area of 212.59 ha (Table 1).

Table 1: Estimated area of the different land cover of the Tanay river watershed

Type	Area (ha)
Orchard	2286.68
Forest	766.14
Grassland	1157.40
Water bodies Residential	176.84
Annual crops	212.59
TOTAL	**4829.67**

On the upper portion of the watershed, the land cover types are mixed deciduous trees, buho (*Schizostachyum lumampao*) and shrubs. The deciduous trees are mostly found in the steep areas of the catchment. There were also patches of small crop production areas found in valleys and gently rolling areas of the upper catchment.

The floodplains are occupied by residential areas and commercial establishments. The remaining areas are mostly planted with rice and vegetables. The gently rolling areas are mostly planted with orchard plants such as mango, coconut, banana and other perennial crops.

Potential areas for reforestation

The mountainous areas located in the upper portion of the watershed are seen as the potential area for reforestation and conservation initiatives. Large areas are covered with grasses and shrubs and have not been inhabited by human (Figure 4). A large portion of the area is within the proclaimed ancestral domain of the Dumagats, hence a potential venue for reforestation and conservation programs.

The area is also guarded by a barangay patrol under the bantay kalikasan program of the Municipality of Tanay. Reforestation programs and other conservation initiatives are also undertaken yearly in the area. This is very useful in speeding up the reforestation and conservation programs to mitigate the negative effect of flooding and related environmental problems within the watershed and in the floodplains of the river.

This will also help boost the eco-tourism activities in the area. The Masungi rock formation is located in this area and it is being developed and promoted as an eco-tourism destination in the town of Tanay.

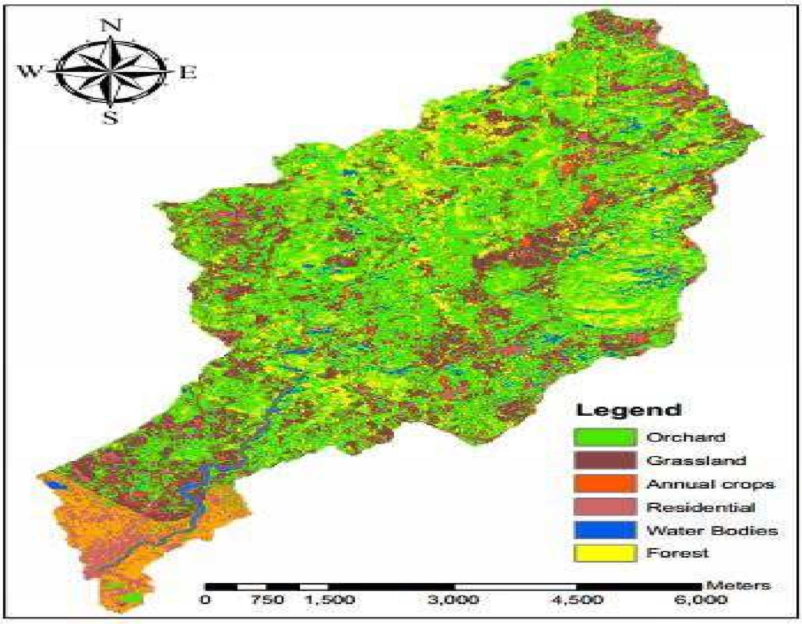

Figure 4: Derived land cover map of the watershed of Tanay River

Land cover scenarios

Two land cover scenarios were prepared to assess their impacts to flooding in the floodplains of Tanay River.

The first is the present land cover of the watershed (Figure 4) and the second is the reforestation of the grasslands in the upper portion of the watershed (Figure 5).

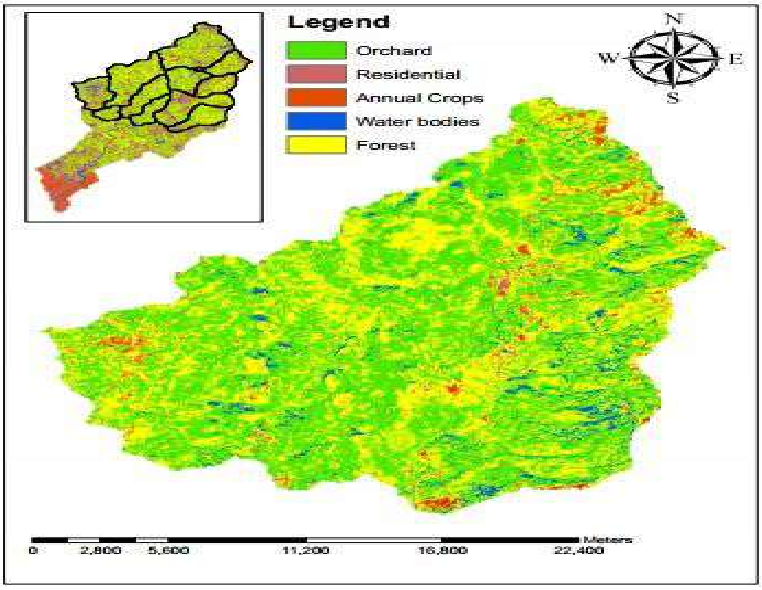

Figure 5: Modified land cover map in the upper portion of the watershed

If the proposed grassland areas in the upper portion of the watershed are reforested, the total forest area will increase from 766.14 ha to 1423.40 ha. About 1230.07 ha is located in the upper portion of the watershed and 193.33 ha is found outside the proposed reforestation area.

Hydrograph calibration

Prior to simulation, the peak discharge of the simulated hydrograph was compared with the computed discharge of the river cross-section using the measured velocity and area in the pre-selected calibration area.

The computed peak discharge is slightly lower than the simulated peak value of the hydrograph. The peak discharge of the simulated and computed hydrograph is 16.9 and 15.7 m^3s^{-1}, respectively.

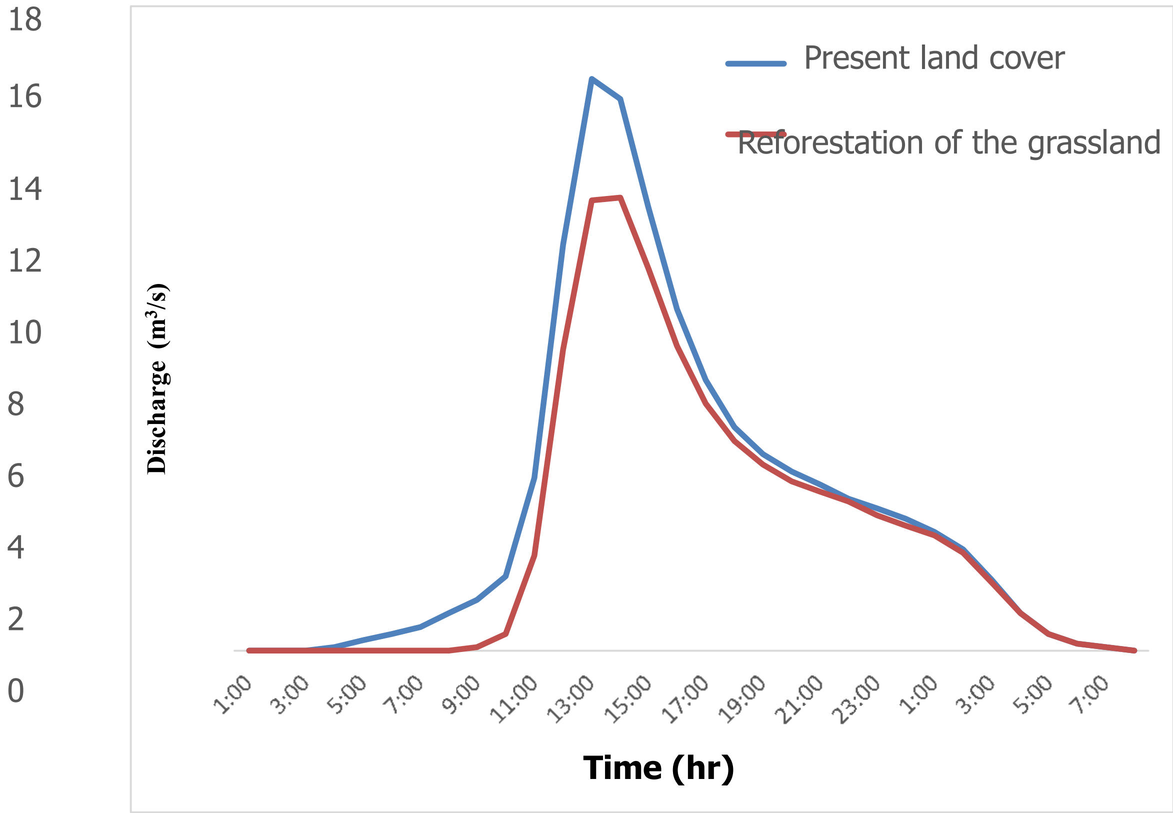

Figure 5: Simulated hydrograph of the middle river network using 80 mm total rainfall

Hydrograph Analysis and Derivation of the Water Depth

The unit hydrograph of the middle river network was derived using the modified land cover as input parameter to HEC-HMS. The peak discharge of the hydrograph was used as flow data in simulating the water level at the pre-selected river cross-section within the middle river network using HEC-RAS.

The simulated unit hydrograph in the middle river network using the derived present land cover had a peak discharge of $16.9m^3s^{-1}$. The peak discharge decreased to $13.4m^3s^{-1}$when the grasslands in the upper portion of the watershed are converted to forests (Figure 5). The depth of water in this portion of the river also decreased from 60 to 52.0 cm.

There was also a considerable decrease of simulated peak discharge at the lower reach of the river. The discharge decreased from 43.8 to $35.7m^3s^{-1}$ when the grassland in the upper portion of the watershed is reforested.

Hecras Model Calibration

Prior to flood simulation, the model was calibrated using the water elevation data that was gathered during a storm on February 22, 2013. The measured water depth of 61 cm coincided with the simulated depth of 60 cm (Figures 6). The computed discharge of $15.7m^3s^{-1}$ in the river cross-section R120 is however lower than the simulated peak discharge of $16.9m^3s^{-1}$ under present land cover condition. The difference could be due to an error in the computation of the cross-section. The river has asymmetrical bottom which cannot be easily captured using surveying instruments.

Flood Flow Simulation

The flood flow was simulated using the derived flow hydrograph of the river under different land cover scenarios (Figure 7).

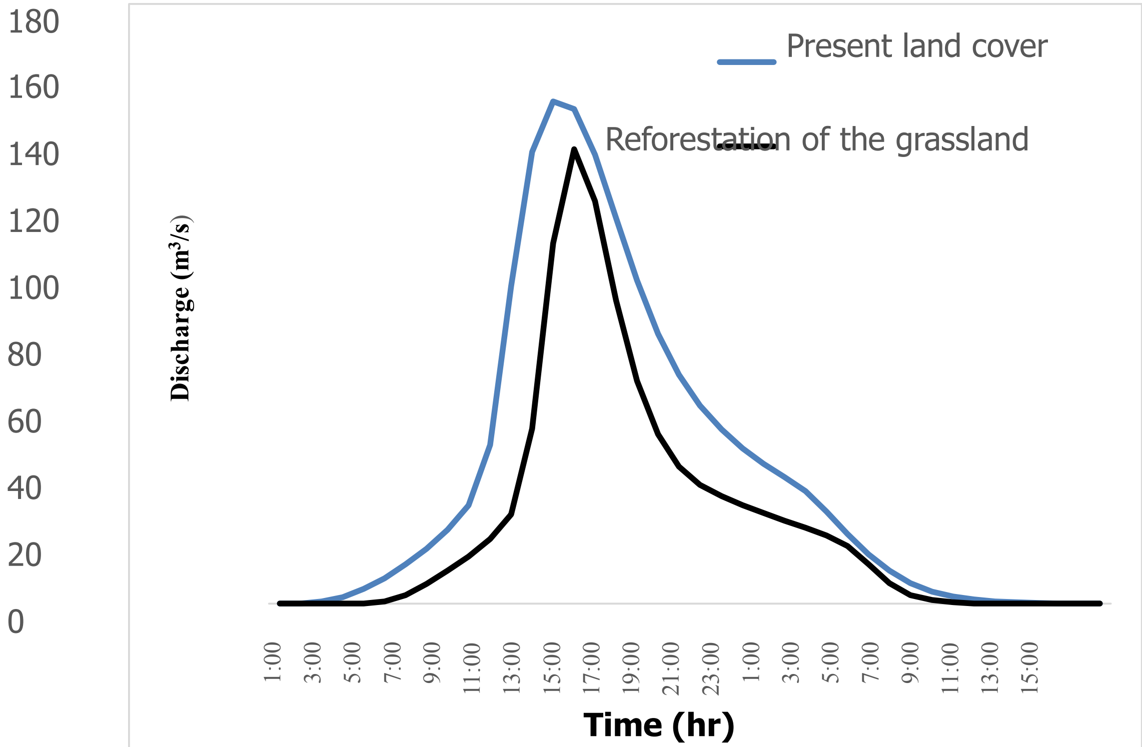

Figure 7: Simulated flow hydrograph in the lower portion of the river

The result of the flood simulation using extreme rainfall data under the present land cover condition of the Tanay micro-watershed indicated that a total area of 5.17 sq km will be affected by low to extreme flooding (Table 2). Almost half of the flooded area is in Barangay Plaza Aldea, the largest barangay in the lowland part of Tanay.

Flood simulation also indicated that a total area of 2.801 sq km may be exposed to extreme flooding and about 1.24 is exposed to moderate flooding. Most of the areas that were exposed to low flooding were found in Barangays Plaza Aldea, Katipunan Bayani, Tandang Kutyo and Wawa (Table 2).

Table 2. Estimated flooded area (sq km) and classification under the present land cover condition using extreme rainfall data

BARANGAY	LOW	MODERATE	EXTREME	VERY EXTREME	TOTAL
Plaza Aldea	0.187	0.495	1.372	0.242	**2.296**
TabingIlog	0.000	0.004	0.021	0.015	**0.040**
Mag-ampon	0.000	0.024	0.072	0.036	**0.132**
KatipunanBayani	0.028	0.109	0.579	0.026	**0.742**
TandangKutyo	0.034	0.062	0.087	0.108	**0.291**
KayButo	0.010	0.071	0.411	0.356	**0.848**
SanIsidro	0.000	0.093	0.119	0.029	**0.241**
Pinagkamaligan	0.000	0.015	0.026	0.010	**0.051**
Wawa	0.018	0.362	0.113	0.035	**0.528**
TOTAL	**0.277**	**1.235**	**2.801**	**0.857**	**5.170**

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The large portion of Barangay KayButo that was classified as very extremely flooded is found in the low-lying areas, along the shore of Laguna Lake. On the other hand, the extremely flooded areas of Barangay Katipunan Bayani were mostly rice fields found in between two national highways with higher elevation (Figure 8).

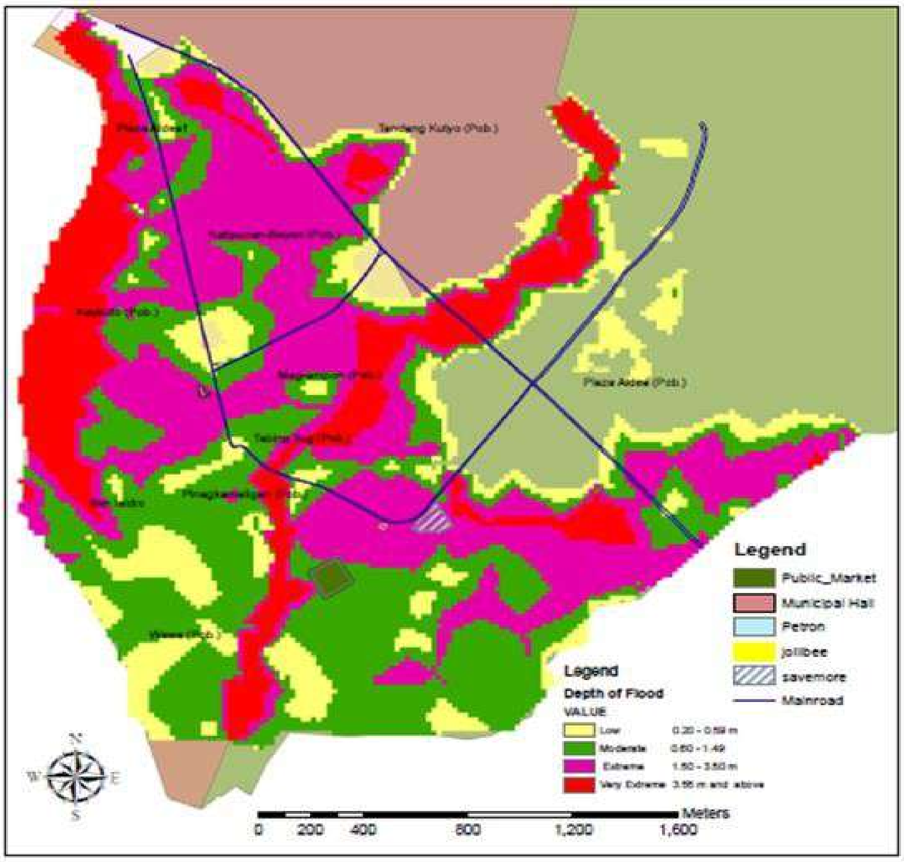

Figure 8: Simulated depths and extent of flooding in the floodplains of Tanay under the present land cover of the watershed

The simulation likewise predicted a reduction in the total flooded area in the floodplains of the river if the grasslands at the upper portion of the watershed are converted to forests (Figure 9). The expected decrease in water depth is about 0.36 m or a total of 16.4 hectares of land in the floodplains of the river will not be affected by flood. About 12.4 hectares is located in Barangay Plaza Aldea.

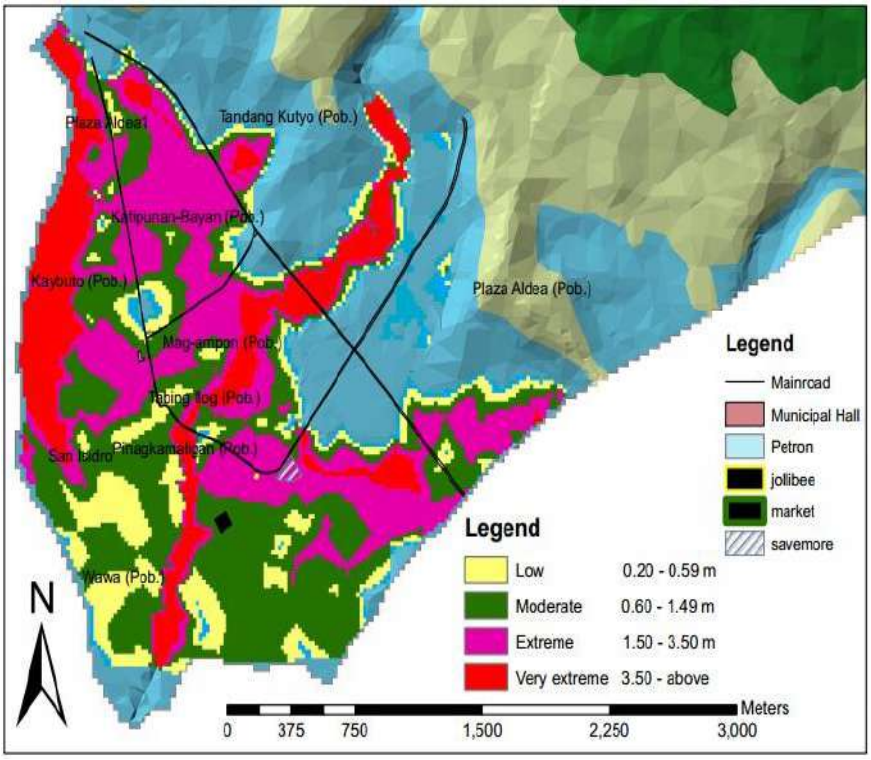

Figure 9: Simulated depths and extent of flooding in the floodplains of Tanay River under the modified land cover of the watershed

The total area which is classified as very extremely flooded is 0.761 sq km. The areas that are classified as extremely flooded decreased from 2.8 to about 2.15 sq km. On the other hand, the low and moderately flooded areas increased to 0.59 and 1.51 sq km, respectively (Table 3).

The decrease in flood depth resulted to the decrease of very extremely and extremely flooded areas and an increase of low to moderately flooded areas in the low-lying areas of the town.

Table 3: Estimated flooded area (sq km) and classification using extreme rainfall data for the modified land cover scenario of the watershed

BARANGAY	LOW	MODERATE	EXTREME	VERY EXTREME	TOTAL
Plaza Aldea	0.253	0.720	0.998	0.201	**2.172**
TabingIlog	0.000	0.008	0.020	0.011	**0.040**
Mag-ampon	0.006	0.034	0.061	0.032	**0.133**
KatipunanBayani	0.058	0.130	0.527	0.011	**0.727**
TandangKutyo	0.045	0.047	0.078	0.099	**0.268**
KayButo	0.024	0.135	0.346	0.341	**0.846**
SanIsidro	0.025	0.118	0.076	0.023	**0.242**
Pinagkamaligan	0.003	0.028	0.012	0.010	**0.052**
Wawa	0.176	0.286	0.030	0.033	**0.526**
TOTAL	**0.590**	**1.507**	**2.148**	**0.761**	**5.006**

Environmental Management and Mitigating Measures

Vegetation cover represents one of the most powerful factors influencing the flood flow regime, since it modifies and moderates the runoff regime of a particular watershed. Increased land cover in the watershed of the area helps moderate the impact of flooding in the floodplains of the town. Watershed response to extreme rainfall event can be used to examine the impact of flooding in the floodplains of the Tanay River.

Most of the watershed located in the upland areas of Tanay had been heavily deforested. Due to this, greater runoff is expected during heavy rainfall. Greater and more intense runoff may also result to higher soil erosion and destruction of the riverbanks that may result to siltation of the river, making the river shallower.

In order to control flooding, there's a need to reforest and implement conservation programs to improve the present land cover of the watershed. It is also crucially important to continuously guard the remaining forest through the bantay kalikasan program of the town to prevent illegal cutting of trees.

5 CONCLUSION

Flood simulation and land cover change analyses offer a practical way of extracting future and unavailable information that are vital to flood vulnerability reduction and management.

The result of the land cover analysis indicated that the watershed of Tanay is predominantly covered by orchard plants and grasses with an area of 2286.8 and 1157.40 hectares, respectively.

The upper portion of the watershed is seen as the most viable area for reforestation. Most part is not yet inhabited and has been the venue of reforestation and conservation initiatives of Tanayans and Rizalenos.

Simulation revealed a reduction of $8.1 m^3 s^{-1}$ peak discharge in the lower river network for an 80 mm total rainfall if the grasslands in the upper part of the watershed is reforested. The estimated reduction in floodwater depth for an extreme rainfall event is 36 cm (418 mm total rainfall), or a total of 16.4 hectares will be spared to flooding.

6 RECOMMENDATIONS

Creation and implementation of holistic environmental programs that will restore the original state of the watershed in the upland barangays of the town is a must. It is also vital to strengthen the local policy framework that protect and conserve the remaining watershed so as to reduce excessive runoff, thereby reducing the geophysical vulnerability of the barangays located in the floodplains of Tanay.

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