Development of a Land Use Management Plan for the Maha-Oya Minicatchment of the Upper Mahaweli Catchment

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ABSTRACT

A study aimed to identify measures for the minimization of land degradation and to develop a sustainable land use management plan, using an integrated approach was conducted in the Maha-Oya Mini catchment in Sri Lanka, using Geographic Information System as the principal tool. The land suitability map of the area was prepared by overlaying land use and the slope map. Geographic Information System results indicated that out of total land, 7485.9 ha (69.5%) were suitable, 1978.6 ha (18.4%) were moderately suitable while, 1311 ha (12.1%) were unsuitable with respect to the slope.

Lands that were indicated unsuitable were suggested some recommendations based on the social requirements and land use policy planning guidelines. Followings were the final recommendations: Annual crops between 30% and 60% slope class (643.4 ha) have to be adopted by strict soil and water conservation measures. Marginal tea lands in above 30% slope (249.6 ha) class should be filled with vegetatively propagated tea or should be diversified. Grasslands in between 30% and 60% slope class (211.2 ha) have to be converted into Kandyan Forest Gardens or community forestry. Forest plantations over 60% slope class (113.7 ha) have to be converted into mixed plantations if they are mono cultures or gradually enrich with indigenous species. Annual crops and grasslands which are above 60% slope class (92.6 ha) have to be converted in to catchment protection area.

KEY WORDS: Upper Mahaweli Catchment (UMC), Maha-Oya Minicatchment (MOC), Geographic Information System (GIS), Land use, Slope, Land Suitability.

INTRODUCTION

The success of the Accelerated Mahaweli Development Programme (AMDP) greatly depends on the water resources of the Upper Mahaweli Catchment (UMC). Sustainability of water resources is imperative for the continued prosperity of Sri Lanka, where economy is largely dependent upon agriculture. Under the AMDP, Mahaweli water is transferred to dry zone of the country through a massive diversion scheme including hydroelectric power generation. The UMC is located in the central hills of the country and it is situated in the wet and intermediate zones of Sri Lanka between 150 m and 2200 m above mean sea level. The total surface area of UMC is approximately 3118 km^2 (Anon, 1992) including the subcatchments of the four reservoirs namely Kotmale, Victoria, Randenigala and Rantambe.

The study was carried out at Maha-Oya Minicatchment (MOC) of Victoria subcatchment in UMC. It is situated in Nuwera-Eliya and Kandy districts and lies within 208 to 222 km N and 190 to 204 km E coordinates. The MOC belongs to three Divisional Secretaries *viz.* Deltota, Hanguranketa and Pathahewaheta. The total surface area of the MOC is 10,775.5 ha and it is 3.5% of the total land area of the UMC. Maha-Oya begins from the Northern region of the Piduruthalagala mountain range and joins Victoria reservoir few kilometers above the Victoria dam.

The present land use of the area consists of government owned and privately managed tea estates, abandoned tea lands, Kandyan Forest Gardens (KFG), perennial crops, paddy, coconut, annual crops, grasslands, forest plantations and natural forests.

The MOC is situated in five different agro-ecological regions namely IM1a, IM3c, IU2, WU2a and WU2b (Anon, 2003). The mean rainfall in the study area ranges from 1100 to 2400 mm per year. The dominant soil type is Red Yellow Podzolics, which occurs in association with Mountain Regosols and Lithosols (Somasiri, 2005).

During the past few decades, land degradation has increased in MOC causing serious problems for achieving long term sustainability of the AMDP. The land degradation in the MOC will lead to following consequences *i.e.*, reduction of the soil fertility and water holding capacity leading to reduction of yield and income level of the farmers in the MOC; siltation of the reservoirs and irrigation structures resulting reduction of capacity and hydroelectric power generation; irregular water flow into the reservoirs with increasing floods during the rainy season and very low water flows during dry season; occurrence of landslides which threaten the human life and activities of the area (Anon, 1992).

This study was carried out to identify measures to minimize land degradation in MOC and to develop a sustainable land use management plan using an integrated approach.

MATERIALS AND METHODS

The digital spatial data of the study area were obtained from the database of the Environment and Forest Conservation Division (EFCD) of the Mahaweli

Authority of Sri Lanka (MASL). The Geographic Information System (GIS) base software, ArcView GIS version 3.2 (ESRI, 1996), was used to generate two digital maps of the study area, *i.e.* land use map and the slope map. Both these maps were at the 1: 10 000 scale, which provided more details of the distribution of spatial variables of the land uses and the slope classes of the study area.

a) The present land use and vegetation in Maha-Oya catchment

The 28 different land uses in the MOC were identified and they were generalized into 10 land uses for this study. The prepared land use map was intensively field checked to detect any changes of the land use with the time. The digital land use map was used to estimate the area of present distribution of different land uses.

b) Slope type of the Maha-Oya Catchment

The slope map of the area was generated using Digital Elevation Model (DEM). The DEM was prepared using digital contours and spot heights. The contour interval of the slope map was 20 m. The five slope classes were used in the slope map. The digital slope map was used to estimate the area of different slope classes.

c) Development of the land use management plan

With the help of GIS, an integrated approach was used to develop the land use management plan. In the process of the development of the land use management plan, field survey was conducted using a pretested questionnaire and Rapid Rural Appraisal (RRA) techniques to identify perceptions and attitudes towards current land use, problems and to identify measures to reduce the problems. A cluster sampling method was used to collect information using 60 respondents. Collected data were analyzed using SAS statistical package (SAS, 1998).

The land use planning guidelines provided by the Land use policy planning division (1988), Land suitability evaluation and land use studies in Nuwara Eliya district by Alwis *et al.* (1981) and Guidelines for forest plantation site selection in the UMC by the Forest/land use mapping project of the MASL (1994) were also used to develop the land use management plan. For the purpose of the development of the land use management plan, unproductive lands, urban and settlements were ignored.

The geo-processing facility available at the ArcView GIS software was used to overlay land use map and the slope map of the study area and statistics were generated. Through the overlaying of the slope map and the land use map, land suitability map was generated. The land suitability map was categorized into three broad categories as suitable, moderately suitable and unsuitable.

Finally, recommendations were made for land uses that have been identified as unsuitable based on social requirements and land use policy planning guidelines.

RESULTS AND DISCUSSION

a) The present land use and vegetation in Maha-Oya catchment

The upper part of the catchment mainly consists of montane natural forests, forest plantations (*Pinus* and *Eucalyptus*) and tea. Upland annuals and paddy fields are distributed in either side of the Maha-Oya. Present land use in MOC and extent is shown in the Table 1.

Table 1. Present land uses in the Maha-Oya catchment

Land use	Area (ha)	Percentage (%)
Well managed tea	1736.7	16.1
Marginal tea	766.2	7.1
Perennial crops	1632.0	15.1
Paddy	1512.3	14.0
Annual crops	1457.3	13.5
Forest plantations	1022.2	9.7
Natural forests	1512.4	14.0
Grasslands	593.4	5.5
Urban and settlements	390.7	3.6
Unproductive lands	152.3	1.4
Total	**10775.5**	**100.0**

The major land use in the study area was tea, covering 2502.9 ha (23.2%). Some of these plantations were managed by the state owned organizations (*eg.* Loolekandura Group by Janatha Estate Development Board) and others by the regional plantation companies (*eg.*Mooloya Estate by Pusselawa Plantations). Well managed tea consisted of 1736.7 ha (16.1%) in the area. The marginal tea lands that consisted of less than 60% vegetative cover over the ground comprised 766.2 ha (7.1%). Perennial crops that included KFG, export agricultural crops *etc.* covered 1632 ha (15.1%).

Paddy was grown in the rolling hilly slopes and ridges using terraced basins to impound water. It is mainly distributed in either sides of the Maha-Oya. Paddy cultivation is confined to rainy season (*Maha*) and during dry season (*Yala*), the fields are brought under the vegetable cultivation.

An area of 1512.4 ha (14%) comprised natural forests. They were distributed in the northern part of the catchment. These forests were classified as montane forests (Ashton *et al.*, 1997) and they are distributed in and around Lulkandura area. This patch of natural forests is a continuation of the northern part of the Piduruthalagla mountain. Forest plantations that consist of Pinus (*Pinus caribaea)* and Eucalyptus (*Eucalyptus grandis*) cover about 1022.2 ha (9.7%) of the catchment.

Grasslands, unproductive lands and urban areas consist of 5.5%, 1.4% and 3.6% of the total land, respectively. Except for grasslands in wet zone, all other grasslands are *dry pathana* (Ashton *et al.*, 1997) as a result of abandoned tea plantations. They are mainly distributed in and around Deltota, Hewaheta areas. The prominent grass species in these grasslands are *Chrysopogan zeylanicus* (Gawara), *Panicum maximum* (Guinea grass), *Ischaemum* spp. (Rata-thana) and *Imperata cylindrica* (Illuk) along with

grasses introduced by the tea estates such as *Cymbopogon confertiflorus* (Mana) (Stocking, 1992).

Unproductive lands consist mainly of rock-out-crops, which are not suitable for any agricultural use due to shallow depth of the soil. There are only 390.7 ha (3.6%) of urban areas and settlements in the study area.

b) Slope type of the Maha-Oya Catchment

The total extent (ha) and the percentage of different slope classes are shown in the table 2. Results indicated that the majority of lands lie between 16% and 30 % slope class. There were only 2.6 % of the lands distributed in the less than 8 % slope class. One important character was that 43.8 % of the total land was above 30 % slope, which was vulnerable to land degradation in the absence of a good vegetative cover or use of soil conservation measures.

Table 2. Different slope classes and their extent

Slope Class	Extent (ha)	Percentage from total extent (%)
<8 %	281.3	2.6
8 – 16 %	1426.6	13.2
16 – 30%	4349.3	40.4
30 – 60%	4146.0	38.5
>60%	572.3	5.3
Total	**10775.5**	**100.0**

c) Development of the land use management plan

The land suitability map was categorized into three broad classes as suitable, moderately suitable and unsuitable (Annex 01). Suitable land uses can be continued with present land use, while moderately suitable land uses have to be adopted by the conservation measures in order to continue with present land use. Land uses that have been identified as unsuitable, either have to be replaced with suitable land use or have to be adopted by strict soil and water conservation measures in order to prevent further degradation of land. The table 3 shows the distribution of the ten land uses and the five slope classes adopted in the study

Statistics generated through GIS revealed that 7485.9 ha (69.5%) were considered as suitable land uses with respect to the slope. Out of the rest, 1978.6 ha (18.4%) were identified as moderately suitable while 1311 ha (12.1%) were considered unsuitable.

Well managed tea lands, perennial crops and paddy were identified as suitable up to 60% slope. Well managed tea lands consist of tea lands which have over 60% vegetative cover. These plantations are owned by both state and regional plantation companies, where large investments in land preparation, drainage, stone walls and infilling planting have been done. Stockings (1992), recorded that the annual soil loss from well managed tea lands was approximately 5 tons/ha/year. Lands which were above 60% slope are recommended as catchment protection areas (Alwis *et al.*, 1981). Hence, the 49.5 ha of well managed tea can be allowed to remain as long as there is good vegetative cover and management with intensive soil conservation practices.

The perennial land use category is another classical example of suitable land uses that can be observed in the catchment where an area of 1609.4 ha up to 60% slopes. It is mainly because of the presence of dense canopy due to multi-story land use. The KFG is a traditional land use of the uplands in the mid-country. It is being strongly promoted for small holders and several sites are in the transitional stage, especially unproductive land uses such as marginal tea lands and grasslands. The area of 22.6 ha which is above 60% slope was identified as moderately suitable lands in the land suitability map. They could be continued with minimal disturbance to the soil, since above 60% slope is highly susceptible to soil erosion. The area of 1508 ha of paddy was identified as suitable land use up to 60% slope because well maintained paddy terraces recorded low level of soil erosion (Stocking, 1992). Only 4.3 ha of paddy above 60% slope were identified as moderately suitable land uses. The natural forests were also classified as a suitable land use. Well managed tea lands, perennial crops and paddy in the catchments considered as sustainable land uses.

An extent of 106.9 ha of the marginal tea below 16% slope was identified as suitable, while 409.7 ha between 16% and 30% slope class were identified as moderately suitable. However, 249.6 ha above 30% slope were identified as unsuitable lands. Stockings (1992), recorded that the annual soil loss due to erosion in marginal tea lands is in between 100 and 200 tons/ha/year, whereas in a well managed tea land it is only around 5 tons/ha/year. An area of 249.6 ha which was found in above 30 % slope has to be in filled with vegetatively propagated tea to increase vegetative cover or convert in to diversified lands. Marginal tea lands were identified as underutilized lands (Anon, 1988).

Annual crops which were cultivated above 30% slope class (700.7 ha) were identified as unsuitable. Field survey results indicated that 88% of the people did not like to shift from annual crops to agroforestry based land use system, which is more suitable to this slope category (Alwis *et al.*, 1981). This was mainly due to cash crops such as vegetables which generate profits within less time period. Hence, to have a sustainable land use with annual crops, it is essential to adopt strict soil conservation measures. The RRA results from the Neelawala colony indicated that people prefer terraced system to adopt in their lands, because of the belief that it will reduce soil erosion effectively and provide much space for cultivation. The Slopping Agricultural Land Technology (SALT) system, which has multiple benefits ranks in the second place mainly due to space requirement for the hedge rows and due to maintenance costs. Stone terraces, grass strips, vetivar grass hedges and mechanical drains (lock and spill) were ranked, from third to six, respectively. The 57.3 ha above 60 % slope has to be converted into permanent forestry with indigenous species (Alwis *et al.*, 1981).

Table 3. Distribution of different land uses on different slope classes

Land uses	Slope classes					
	<8%	8%-16%	16%-30%	30%-60%	>60%	Total(ha)
Well managed tea	16.7*	203.1*	799.1*	668.3*	49.5**	1736.7
Marginal tea	9.2*	97.7*	409.7**	241.5***	8.1***	766.2
Perennial crops	31.0*	229.5*	761.0*	587.9*	22.6**	1632.0
Paddy	154.5*	425.3*	638.5*	289.7*	4.3**	1512.3
Annual crops	25.5*	157.2*	573.9**	643.4***	57.3***	1457.3
Forest plantations	0.4*	37.8*	272.0*	598.3**	113.7***	1022.2
Natural forests	7.8*	70.6*	357.5*	802.7*	273.8*	1512.4
Grasslands	6.5*	87.7*	252.7**	211.2***	35.3***	593.4
Urban and settlements #	12.2*	90.9*	219.5*	67.6**	0.5***	390.7
Unproductive lands #	17.5*	26.8*	65.4*	35.4*	7.2*	152.3
TOTAL (ha)	**281.3**	**1426.6**	**4349.3**	**4146.0**	**572.3**	**10775.5**

suitable, ** moderately suitable, *** unsuitable land uses with respect to slope, # ignored in the study

Results indicated that majority of people living in the study area oppose pine plantations. Different perceptions on pine plantations were analyzed using Chi-square test for specified proportions (Table 4). All the responses were significantly different at 0.05 probability level (chi-square < 0.0001). The 55% of the people in study area identified pine as bad to the area. People in the area reported negative impacts of pines on natural resources *i.e.*, depletion of the ground water, absence of undergrowth (biological deserts), effect to the bio diversity imbalance of the area *etc.* Only 5% identified it as good to the area.

Table 4. The perception on Pine plantations

Response to *Pinus*	Percentage (%)
Very good	0.0
Good	5.0
Moderately good	15.0
Bad	55.0
Very bad	25.0

Moreover, GIS results indicated that 113.7 ha of forest plantations lying above 60% slope were unsuitable because it causes high rate of soil erosion at the time of harvesting. A typical character of these exotic species is that their growth rate is fast and covers the bare soil within a short period of time. However, from the hydrological point of view, *Pinus* plantations are not suitable for a hydro-catchment, since fast growth will eventually reduce water yield of the catchment. Research carried out by the Fiji Pine Commission in collaboration with University of Amersterdam, depicts that pine plantations cause water decline from the sixth year of plantation establishment (Jayakody *et a l.*, 2003). Further, *Pinus* records higher rate of evapotranspiration. Additionally, annual fire causes high rate of soil erosion in above 30% slopes (Rajapakse, 2005). Therefore, in order to have a sustainable land use, these pine plantations have to be replaced gradually with indigenous species, and pine monocultures have to be converted into mixed plantations (Anon, 1994).

Grasslands in the catchment were identified as underutilized lands (Anon, 1988).These underutilized lands carry a potential of converting into cultivations or into other productive land uses. Grasslands situated above 30% slope (246.5 ha) were considered as unsuitable because of annual fires. The *pathana* grasslands are often burnt annually during January to February and July to August, apparently to control pests or as a result of vandalism. This is one current issue prevailing in the catchment. This annual burning has resulted in pyro-climax vegetation and has prevented the re-establishment of woody species through plant succession (Anon, 1990). This also causes high rate of erosion during the rainy season. The people living in the study area suggested that these underutilized grasslands could be converted into KFG which possess multiple benefits or to community forestry. Another alternative use for below 60% slope is planting of Bamboo species such as *Indocalamus vulgaris* and *Davidsia walkeri* since bamboo provides continuous vegetation which will ensure soil conservation and surface stability. Moreover, it provides raw materials for cottage industries such as basket weaving which generates additional income to the villagers (Rajapakse, 1993). The above 60% slope of the grasslands (35.3 ha) has to be converted into catchment protection area (Alwis *et al.*, 1981).

CONCLUSIONS

The study revealed that the active participation of land users is essential to formulate a land use management plan, rather than developing a technically feasible land use management plan. Therefore, participation of land users as well as stakeholders is essential in the development of a land use management plan. This study shows that GIS can be used as a powerful tool in land use planning process. Table 5 gives the recommendations for land uses which were identified as unsuitable. Proposed land use/ management map for the MOC which includes recommendations for unsuitable land uses is given in Annex 02.

Further researches have to be conducted on the selection of indigenous tree species suitable to be planted in the catchment and development of the fire control plan with participation of the people.

Table 5. Recommendations for unsuitable land uses

Land use category	Slope class (%)	Extent (ha)	Recommendation
Annual crops	30 - 60	643.4	Adopt strict soil and water conservation measures.
Annual crops	> 60	57.3	Catchment protection purpose only.
Marginal tea lands	> 30	249.6	Fill with VP tea or diversification.
Grasslands	30 - 60	211.2	Convert into KFG or community forestry.
Grasslands	> 60	35.3	Catchment protection purpose only.
Forest plantations	> 60	113.7	Mono cultures into mixed plantations. Gradual introduction of indigenous species.

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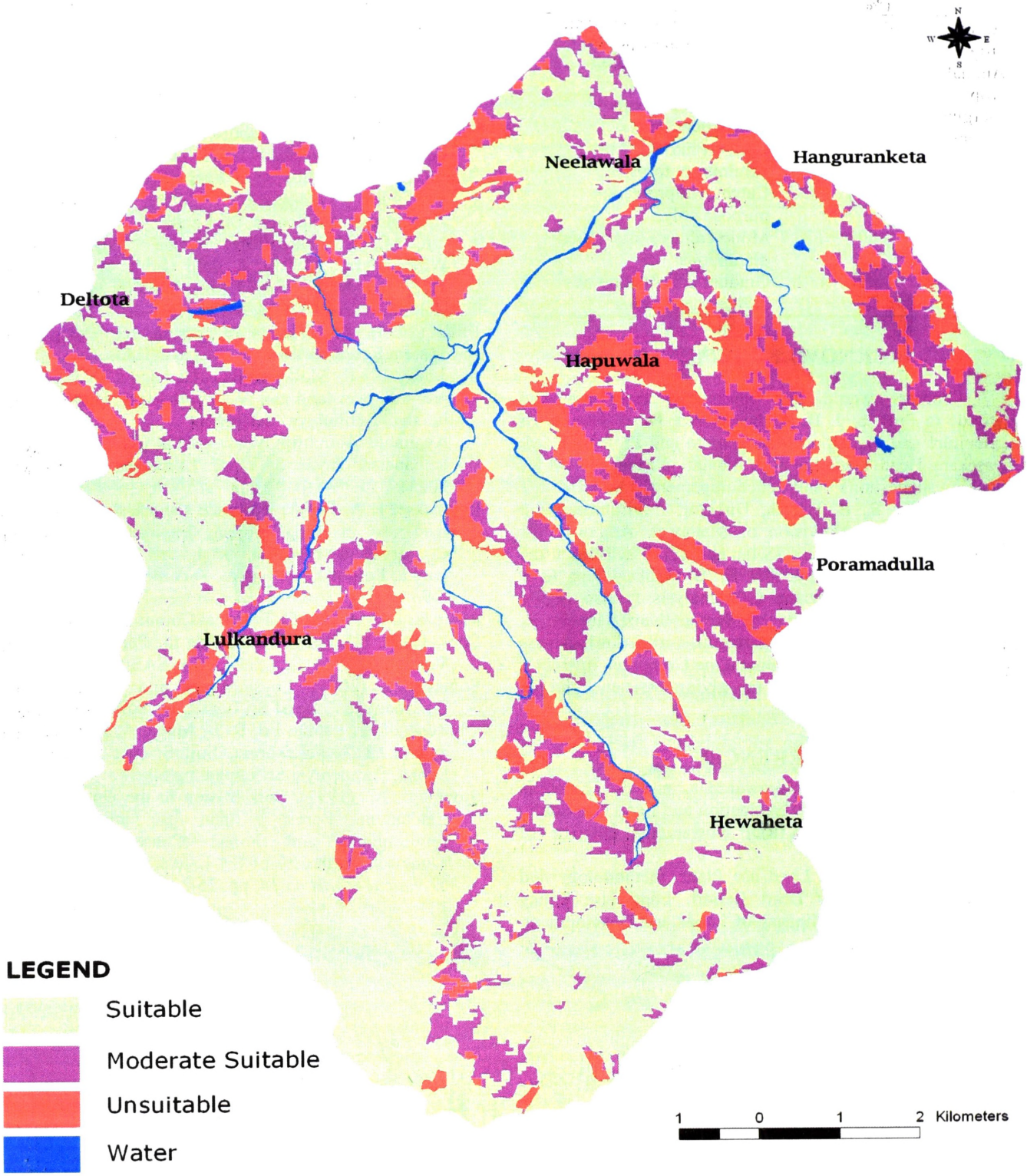
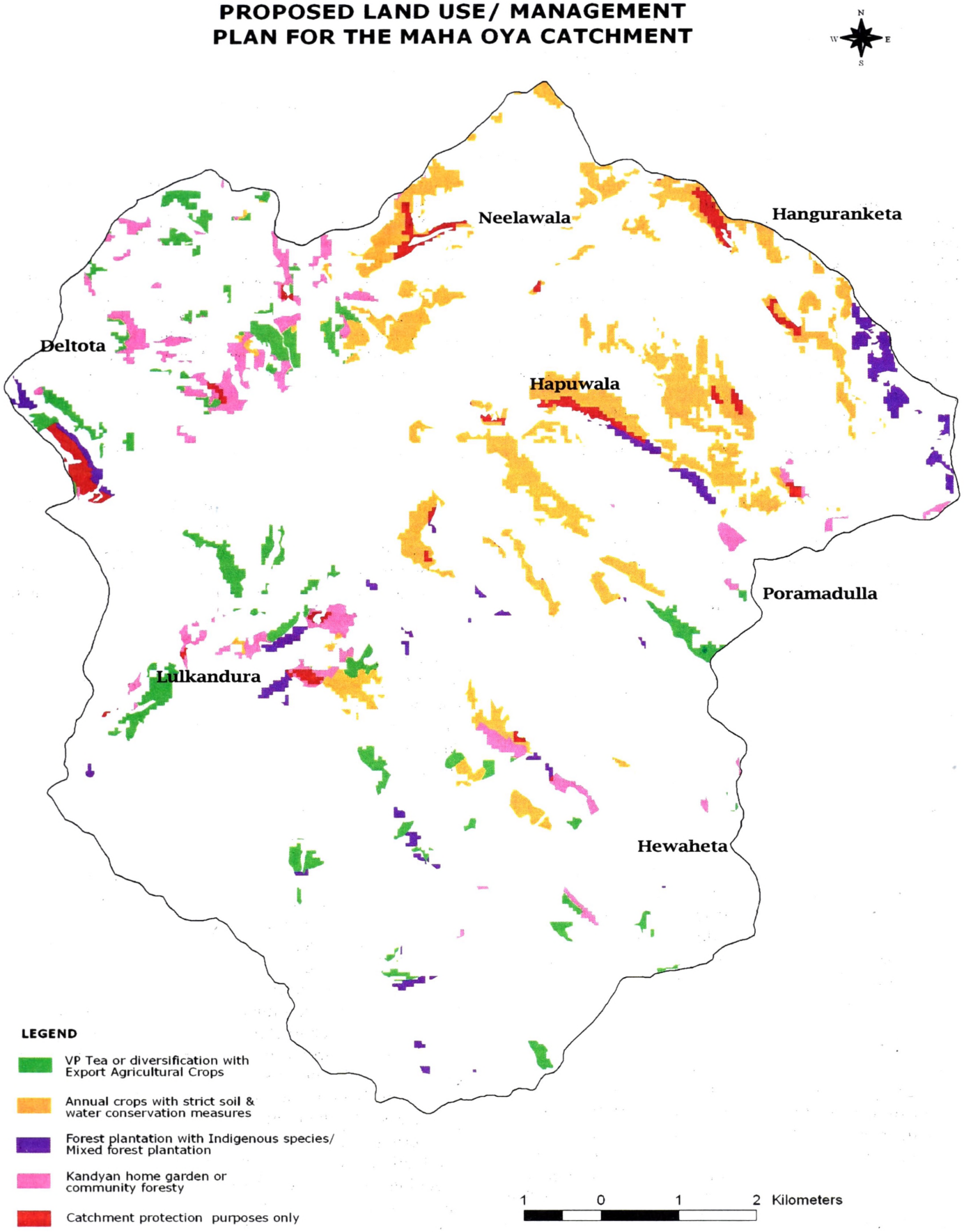
Annex 01

LAND SUITABILITY MAP OF THE MAHA OYA CATCHMENT



Annex 02


PROPOSED LAND USE/ MANAGEMENT
PLAN FOR THE MAHA OYA CATCHMENT
N
W
E
S
Neelawala
Hanguranketa
Deltota
Hapuwala
Poramadulla
Lulkandura
Hewaheta
LEGEND
VP Tea or diversification with Export Agricultural Crops
Annual crops with strict soil & water conservation measures
Forest plantation with Indigenous species/ Mixed forest plantation
Kandyan home garden or community foresty
Catchment protection purposes only
1 0 1 2 Kilometers