Spatial and Temporal Modeling for Sustainable Management of Tropical Rainforest

The Fuelwood Issue in the Cibodas Biosphere Reserve, West Java

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1. Abstract

The aim of this research was to develop a methodology to integrate information on the spatial and temporal diversity of tropical rainforest ecosystems, including both biophysical and human aspects, and to apply this information in integrated environmentally sound management of the natural resources of the tropical rainforest of the Cibodas ecosystem, West Java. Furthermore, the model should not only consider the "protected" area itself, e.g., the Gede-Pangrango National Park, but should take the surrounding areas with human activities (where the impact is often coming from) in consideration as well.

Therefore, a spatial and temporal modeling system has been developed as a user-friendly tool for decision makers e.g., managers, planners and others involved in the (sustainable) management of the tropical rainforest ecosystem. The developed modeling system combines both spatial and temporal data together with other attribute (e.g., statistical) data in such a way, that it is able to simulate the processes going on in the ecosystem, in space and in time; the result will be a spatial presentation (with qualitative and quantitative data) of the expected result of a certain management simulation. In that way the user should be able to examine and evaluate the effects of certain management decisions on the ecosystem functioning, before taking them into practice.

Such a modeling system has been developed for and implemented in the Cibodas Biosphere Reserve in West Java, Indonesia. The Cibodas Biosphere Reserve is an area of humid tropical rain forest, partly surrounded by production forest, tea plantations and agricultural land. The tropical rain forest is under high pressure of the rapidly growing human population, around the protected forest. The result of the model, developed for the Cibodas Biosphere Reserve, representing the actual situation, indicates clearly where and in what extend fuelwood shortages exists and where impact on the national park can be expected. Several simulations of different management possibilities are demonstrating in what extent a specific management option will probably reduce the impact on the national park. But only a combination of several management options seems to be able to reduce the impact on the National Park substantially.

2. Concept of the Management Model for the Cibodas Biosphere Reserve

The problems occurring in the Cibodas Biosphere Reserve, concerning the degradation of the natural forest in the Gede-Pangrango National Park because of illegal collection of forest products e.g., fuelwood, are described in Toxopeus (1996) and the demonstration package, called "Cibodemo", belonging to this paper.

To be able to conserve the natural forest of the Gede-Pangrango National Park, managers need information concerning the location and extent of actual forest degradation and the potential threat of forest degradation in the protected Gede-Pangrango National Park, by illegal fuelwood collection. Moreover, to be able to manage this ecosystem in a sound and sustainable way, they need information concerning the location and extent of the increasing demand for fuelwood, the availability (production) of fuelwood and the accessibility to (potential) available fuelwood.

Changes are relatively slow in the Cibodas Biosphere Reserve. Therefore, the model should be able to show not only the actual situation of the Cibodas Biosphere Reserve. But it should be able to predict future developments in the Biosphere Reserve over a relative "long term" period (two, five or more years), without any management changes (just leave it as it is and lets hope for the best) or simulating management activities and showing its possible positive or negative effects on and consequences for the natural forest, socio-economic situation of the local people, etc. in the Cibodas Biosphere Reserve.

In this case the main cause of the degradation of the natural forest is the collection of forest products, which is in fact caused by the increasing demand for forest products, which is in turn caused by a very high growth of the local human population. Therefore, the demand-aspect is varying in time. Although the availability- and accessibility aspects change in time as well, these changes are not that fast and the changes are relatively easily to update in the model. Therefore, the availability- and accessibility aspects are in principle considered to be constant.

To be able to construct this model, which is calculating and displaying the spatial and temporal variation of the expected impact of fuelwood collecting in the core zone of the Cibodas Biosphere Reserve, data has to be collected and analyzed concerning the fuelwood production of various land cover types, the fuelwood demand or consumption in the area and the accessibility to the fuelwood sources e.g., the Gede-Pangrango National Park (core zone). A description concerning the analysis and procedures followed to build the model, is given in the following sections.

2.1 The Fuelwood Availability (Supply) Aspect

2.1.1 Land Cover Classification

The land cover in the Cibodas Biosphere Reserve has been classified using satellite imagery (TM image 1991), aerial photographs (scale 1:50.000) and other existing maps. Furthermore, field surveys has been carried out to verify and update the classification (Danudoro, 1993, Wiyanto, 1990). This resulted in the identification of seventeen different land cover types.

2.1.2 Fuelwood Production per Land Cover Ttype

On the basis of additional research (Suhaedi, 1992) and analysis of existing literature (Bekkering and Rusmanhadi, 1987, de Gier, 1989, Hueruman, 1979, RADEP, 1986, RADEP, 1987a, RADEP, 1987b, Smiet, 1990, Smiet et al., 1990, Wiersum, 1976) the fuelwood production per hectare per year of the different land cover types has been estimated.

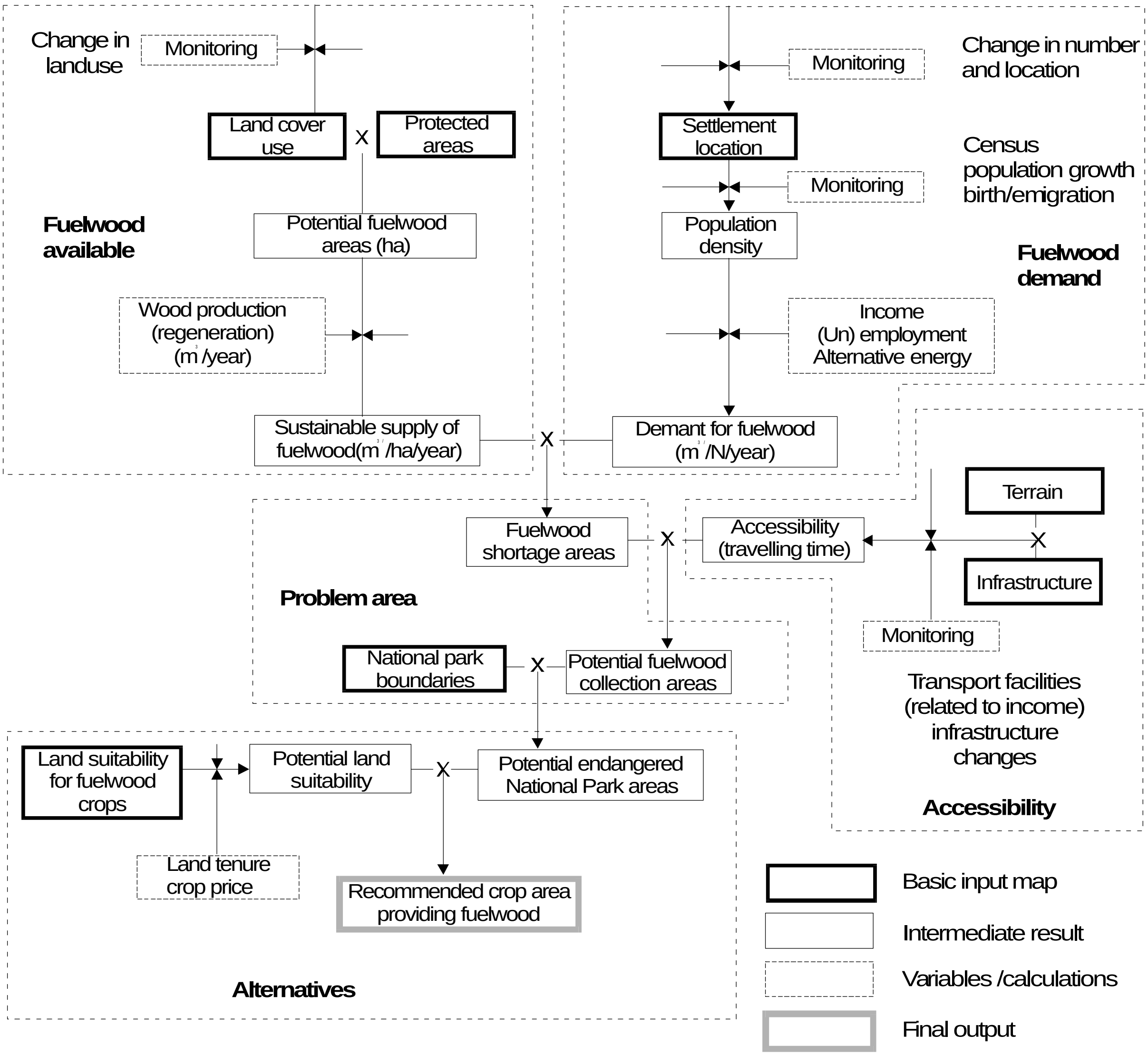

Figure 1. Basic structure of the Cibodas Fuelwood model.

Although the National Park is producing a considerable amount of wood, suitable for fuelwood, this area is strictly protected and, therefore, the fuelwood production is considered to be zero for the purpose of the model building and considered as one cover type as well.

Figure 2. **A mixed garden, with small scale tea, banana and clove trees.**

Figure 3. **A Fuelwood Plantation (Albizzia falcata).**

Table 1. **Fuelwood Production (m^3/ha/year) per Land Cover Ttype in the Cibodas Biosphere Reserve**

Land cover type	Fuelwood production (m^3)
Settlements	0.0
Lake	0.0
Fish pond	0.0
Sawah: rice (1x), vegetables	0.5
Sawah: rice (2x), vegetables	0.3
Sawah: rice (3x)	0.1
Dryland vegetables	0.7
Dryland cashcrops	0.7
Mixed garden	3.5
Homestead garden	5.2
Dryland tumpang sari	4.0
Irrigated land and vegetables	0.7
Tea estate	1.2
Production forest	2.2
Unproductive forest and abandoned tea	7.5
Fuelwood plantation	17.5
National Park	0.0

2.1.3 Fuelwood Production per Desa

In order to calculate the fuelwood production per smallest administrative unit (also referred at as 'desa') based on the land cover types in the area, the administrative unit map has to be combined with the land cover map.

To calculate the sum of the fuelwood production of all the individual areas of the classified different land cover types within each administrative unit, the fuelwood production values are linked to the land cover types:

$$FWA_{desa}\left[\frac{m^3}{year}\right] = \sum_{n=sawah}^{fuelwood\ plantation}\left(Production_n\left[\frac{m^3}{ha * year}\right] * Area_n\,[ha]\right) \quad (1)$$

FWA_{desa} = FuelWood Available per 'desa' in m^3/year.

2.2 The Fuelwood Demand Aspect

The demand for fuelwood is determined by population size and the fuelwood consumption per capita. Therefore, it is necessary to know where settlements are located and the number of people inhabiting these settlements.

2.2.1 Population Number and Distribution per Settlement

The settlement locations are known from existing detailed maps (topographical maps and maps from BPN). The basic population statistics are available per desa (smallest administrative unit) from 1984 up till 1992. As there are many settlements per desa and all the people are assumed to live in one of these settlements, extrapolation of the population over the settlements in each desa was based on the areal fraction of each settlement per desa:

$$P_x = \frac{A_x}{\sum_{x=1}^{n} A_x} * P_t \quad ($$

P_x = Population for settlement x.
A_x = Area of settlement x.
P_t = Total population per desa.
n = Number of settlements within a desa.

Furthermore, the fuelwood demand per desa is based on the number of inhabitants per part of the desa, which is located within the Cibodas Biosphere Reserve (CBR) boundary:

$$PopCBR_{desa} = Pop_{desa} * \left[\frac{\sum_{i=1}^{inside\ CBR} SettleArea_i}{\sum_{n=1}^{all} SettleArea_n}\right] \quad ($$

$PopCBR_{desa}$ = Population number of the desa (part), located within the Cibodas Biosphere Reserve.
Pop_{desa} = Total population per desa.

$SettleArea_n$ = Total settlement area of the whole desa.
$SettleArea_i$ = Total settlement area of the desa(part), located within the Cibodas Biosphere Reserve.

To be able to calculate the fuelwood demand for other (future) years, the estimated population growth rate of 3.1 percent will be used for extrapolation of the population values to the year of calculation:

$$Popnew_{desa} = PopCBR_{desa} * \left[\frac{PopGrowth}{100} + 1 \right]^{(Year-1992)} \quad (4)$$

$Popnew_{desa}$ = Population number of the desa for the year of (model) calculation.
$PopGrowth$ = The estimated population growth.

2.2.2 Fuelwood Consumption

The population values per desa calculated for a particular year of calculation can be multiplied by the fuelwood consumption per capita to obtain the fuelwood demand:

$$FWDpop_{desa} \left[\frac{m^3}{year} \right] = Popnew_{desa} [N] * Concap \left[\frac{m^3}{N * year} \right] \quad (5)$$

$FWDpop_{desa}$ = Fuelwood demand per desa, based on the population numbers of the desa.
$Concap$ = Fuelwood consumption per capita.

The fuelwood consumption is estimated at 0.6 m^3 per capita per year (Affif, 1991 and Suhaedi, 1992). The home- and other small scale industries or export consume about 4.1% of the total amount of fuelwood (Affif, 1991, Bekkering and Rusmanhadi, 1987, Hueruman, 1979, Kuyper and Mellink, 1983, RADEP, 1986, Smiet, 1990, Soesastro, 1985, Suhaedi, 1992, Wiersum, 1976). So, the households account for 95.9 % of the total fuelwood consumption.

2.2.3 Fuelwood Demand

By combining the fuelwood consumption values with the estimated number of inhabitants per settlement, the total fuelwood consumption (demand) per desa can be estimated:

$$FWDtot_{desa} \left[\frac{m^3}{year} \right] = FWDPop_{desa} \left[\frac{m^3}{year} \right] * \frac{100\ [\%]}{HomeCons\ [\%]} \quad (6)$$

$FWDtot_{desa}$ = Total fuelwood consumption (demand) of the desa.
$HomeCons$ = Contribution of the households (%) to the total fuelwood consumption of the desa.

2.3 Fuelwood Surplus or Shortage

Comparing fuelwood production and fuelwood consumption per settlement, results in spatial information concerning the amount of fuelwood surplus or fuelwood shortage per settlement (inside the Cibodas Biosphere Reserve).

If there is an estimated fuelwood shortage in a certain area (settlement), it is assumed that the shortage of fuelwood is collected from nearby settlements with a surplus or from the core zone (National Park).

2.4 The Accessibility Aspect

Another aspect of the model is the accessibility to the National Park. The easier to access, the sooner people tend to go into the National Park for collecting fuelwood, especially if there is a shortage. Therefore, the existence of infrastructure, different types of land cover, the protective function of a buffer zone, the slope steepness and of course the location of the settlements are taken in consideration. In other words, the "travel time" from a certain settlement with fuelwood shortage to areas with a surplus of fuelwood (e.g., the National Park) is a function of slope steepness, infrastructure, land cover type and distance (Mannathoko et al., 1990).

2.4.1 Infrastructure and Land Cover

The infrastructure was classified on the basis of five different road types, each with a specific travelling speed (in km/hour). The different land cover types were also classified according to the expected walking speed (Mannathoko et al, 1990).

Table 2. The travelling speed per infrastructure (road) type in the Cibodas Biosphere Reserve

Road Type	Travelling speed (km/hr)
Trail	3.0
Horse path	4.0
Secondary road II	6.0
Secondary road I	6.0
Main road	6.0

Table 3. Travelling speed per land cover type in the Cibodas Biosphere Reserve

Land cover type	Travelling speed (km/hr)
Settlements	6.0
Lake and fish ponds	0.0
Sawah	2.0
Dryland vegetables and cashcrop	2.0
Mixed – and homestead garden	1.5
Dryland tumpang sari	2.0
Irrigated land and vegetables	2.0
Tea estate	2.5
Production forest and fuelwood plantations	1.0
Unproductive forest and abandoned tea	0.7
National Park	0.5

2.4.2 The Buffer Function

The introduced "buffer function", expresses the percentage of the population, that will go to the National Park by crossing the buffer zone. This function does not really delay the travel, but has a disencouraging effect on for people who want to cross the zone. For production forest owned by Perum Perhutani, it is a fact that people who are not employed by Perum Perhutani, are not allowed in this area. The same holds for the tea estates, but because people crossing the tea estates are more easy to detect, the discouraging function is much higher. Based on personal observations and interviews with local authorities (e.g., PHPA), the "buffer function" for production forest is assumed to be effective for 50 percent and for the tea estates only 20 percent of the number of people, expected to pass through.

2.4.3 Slope Steepness

The slope steepness of the area will also influence the accessibility to the National Park. By interpolating the contour lines (digitized from existing topographical maps) a map of the slope angles (in percent) can be created. The steeper the slope the more it will reduce the travelling speed. Therefore, slope steepness has been classified according to the expected influence on the travelling speed, called the slope correction factor (Mannathoko et al., 1990). These slope steepness correction factors will be applied to estimate the final travelling speed per land cover type. By combining the accessibility factors with the settlement locations map, the expected travelling time from each settlement into the National Park was calculated.

Table 4. The slope steepness classes and the correction factors applied to the travelling speed in the Cibodas Biosphere Reserve

Slope steepness	Slope correction
0% - 5%	1.00
5% - 10%	0.96
10% - 20%	0.82
20% - 30%	0.65
30% - 45%	0.50
45% - 65%	0.41
65% and higher	0.29

2.5 The Impact Assessment for Cibodas National Park

To estimate the vulnerability of the National Park, the calculated expected travelling time from each settlement to the National Park is combined with the "motivation" of the people per settlement to collect fuelwood from the National Park. The "motivation" is based on the relative fuelwood shortage for each settlement.

Settlements with a fuelwood shortage will be used as starting points for an accessibility calculation, taking as weight the "travelling speed" values per cover type, reduced by the slope correction factor. The settlements with a shortage have boundary areas around them with values proportional to the inverted shortage of the settlements, to simulate "motivation". When the shortage is low, the values of the surrounding boundaries should be high. High values reduce "travelling speed" in the distance calculation process (ILWIS, 1993). Therefore, low fuelwood shortage gives high resistance values around settlements (low motivation) and high fuelwood shortage gives low resistance values around settlements (high motivation).

The classes, used for the spatial display of the expected impact on the National Park, are conditioned by the amount of fuelwood shortage, calculated for the Cibodas Biosphere Reserve. The result of the model, which is based on the year 1992, of the expected impact in the National Park is expressed in the four classes of impact: 1 (severe), 2 (moderate), 3 (low) and 4 (no impact). The statistical data (real data) on the quantities of fuelwood available, the demand for fuelwood and the shortage of fuelwood can be displayed for each desa separately.

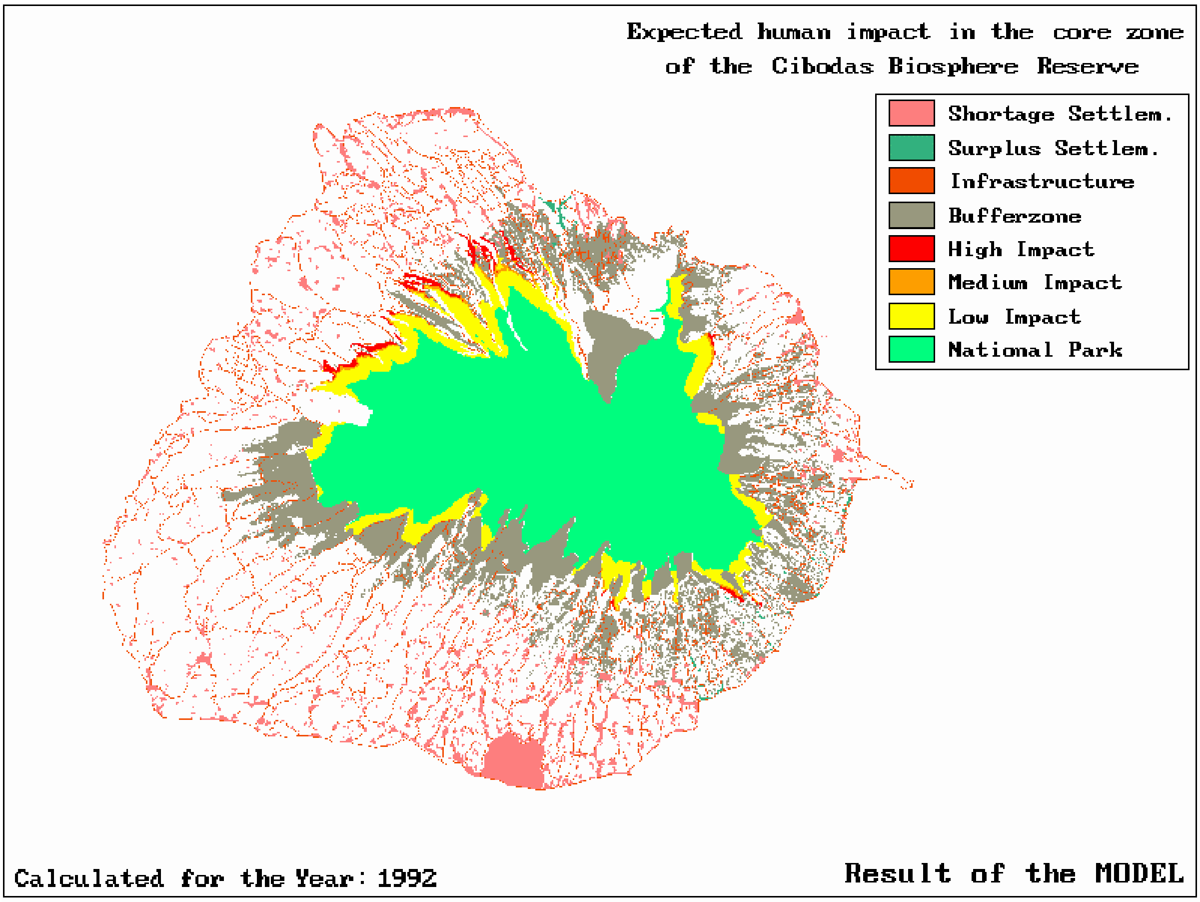

Figure 4. **The result of the model (based on 1992), indicating the intensity of expected impact in the National Park, due to illegal fuelwood collecting.**

The result of the Cibodas fuelwood model is a presentation of the actual situation (in this case 1992) concerning the impact of fuelwood collection, occurring in the National Park, the core area of the Cibodas Biosphere Reserve. This result should serve decision makers in the Biosphere Reserve by informing them where and to what extent the core zone is likely to be affected by (illegal) fuelwood collection by local people so that proper management action can be taken.

3. Validation of the fuelwood model for the Cibodas Biosphere Reserve

The present situation (1992) was simulated by using the Cibodas fuelwood model. To validate the result, calculated by the model, independent field data was needed. Although some authors agree to a certain extent that there is destruction of the natural forest of the National Park, caused by illegal fuelwood, timber and other forest products collection, others have the opinion that there is hardly any impact at all or that the secondary forest is a result of logging activities in the past (Meijer, 1959, Wiyanto, 1990, Yamada, 1975).

Unfortunately, no quantitative data about the possible destruction was available so far. Therefore, a field survey (September - October, 1992) was carried out to collect quantitative data about the degree of destruction (impact) of the natural forest of the National Park by fuelwood (and timber) collection.

3.1 Methodology

The samples were subdivided in a number of sub-samples with the first sub-sample was always taken in the national park, close to the national park boundary (indicated by a marked PHPA boundary post). From there, more sub-samples were taken till no signs of destruction were noticed any more. If useful, the second sub-sample was taken 100 m inside the park, the third sub-sample 250 m park inwards, the fourth 500 m inwards, the fifth 1000 m inwards, etc. till no destruction was observed any more. The average (sub-) sample size was 50 x 20 meters.

The impact was measured in terms of to the observed "illegal" wood cutting and categorized according to the different stem-diameters. Only recent cutting, assumed to be less than one year old, was counted. Cuttings already overgrown with mosses, fungi or otherwise clearly were not counted. Cuttings clearly associated with maintenance of official (PHPA) trails were not included either.

To classify the impact of wood cutting on the natural forest, as measured during sampling, the number of cuttings and the average stem diameter of the cut wood were considered. A conversion table, to convert stem diameter (ϕ cm) to woody biomass (m), as applied in forestry (Byram et al., 1978, Cunia, 1979, FAO, 1984, de Gier, 1989, Stanek and State, 1978). The estimated loss of woody biomass per sample (total of 1,25 ha / sample) is the summation of the calculated woody biomass loss in m^3 per stem diameter class.

The estimated (classified) impact on the natural vegetation in the National Park is based on the expected loss of woody biomass (m/ha) per sample per year, compared to (% of) the estimated woody biomass (250 m/ha) of undisturbed forest in the National Park. The estimated woody biomass of undisturbed forest is the average of the reported woody biomass in undisturbed tropical evergreen rainforests, given by a number of authors (Bekkering, 1989, de Gier, 1989, Jordan, 1983, Kimmins, 1987, Oldeman, 1988, Paterson, 1956, Persson, 1974, Whittaker and Woodwell, 1971).

Table 5. Classification of the impact per sample. The classification is based on according to the percentage of woody biomass loss per year for each sample, compared with the woody biomass of undisturbed samples

Impact class	impact	Loss of woody biomass (%)
0	No impact	0
1	Little	5
3	Moderate	10
4	Severe	25

It is very difficult to assess the real impact on the natural forest of illegal wood cutting per stem diameter. Wood cutting occurs in different sample units, each with a different floristic composition and structure. So, the impact of the wood cutting in these different samples will be different even if the measured cuttings are comparable. Secondly, the cuttings are measured and counted. Cuttings per species were not recorded, but it makes a big difference in the impact if the cut species belongs to primary forest or to secondary growth. Thirdly, the small (young) trees are essential for the regrowth of the forest. To what extent the cuttings of small trees will have an impact on the natural forest in relation to restoration is also unclear.

Therefore, the classification of the impact of wood cutting on the natural forest is only an indication, based on a generalized calculation.

For each sample the buffer zone type (production forest, tea estate or rainfed- or irrigated agriculture) the length of the buffer zone (from the beginning of the trail through the buffer zone till the national park boundary) has been indicated. The distance from the settlement or village nearest to the national park boundary has been considered as well, including all kinds of accessibility aspects, like roads, trails, rivers etc. A sketch map was prepared, to make the situation as clear as possible. Other relevant information concerning the sample, like location, altitude, other disturbances etc. has been added. A relevee sheet was developed to collect all relevant data in a consistent way, so that the different samples can compared.

3.2 Results of the field survey

During the fieldwork twenty sample areas are surveyed in different locations along the boundary of the National Park (core zone), in the Cibodas Biosphere Reserve. Where the sample starts the number of the PHPA-National Park demarcation was registered and also the nearest village to the National Park boundary. The administrative units e.g., desa, kecamatan and kabupaten to which the nearest village belongs is registered and the location of the sample in the Biosphere Reserve.

Figure 5. Severe impact due to illegal wood cutting in the Gede Pangrango National Park. Agricultural activities were very close to the boundary of the National Park, because there was no buffer zone.

Figure 6. Encroachment (illegal clearing and agriculture) into the Gede Pangrango National Park.

The observed impact (destruction) of the natural forest of the Gunung Gede Pangrango National Park is mainly due to illegal forest product collection. In most cases this is because illegal (fuel) wood collecting by local villagers, but in some cases by introduced labour (working in Perhutani logging or replanting areas, Tumpang Sari or working on large-scale agricultural fields). The level of the observed impact might be influenced by several factors that influence the number of people going into the natural forest to collect these forest products. All these factors have an influence on the level of impact. Therefore, it is not possible with the limited number of samples taken to draw conclusions about the impact of individual factors but some factors clearly have a considerable influence the rate of impact on the natural forest.

If no buffer zone is present and agricultural fields border on the National Park, there is in general a severe impact on the natural vegetation of the National Park. Furthermore, if settlements are close to the National Park, a severe impact is often found. The influence of the presence of a fuelwood plantation is not clear, but it is to be expected that if fuelwood is not for free, the effect will be little (Toxopeus, 1992). When comparing the results from the field survey with the results from the model, it was found that the results of the model corresponded well with the evidence collected during the field survey.

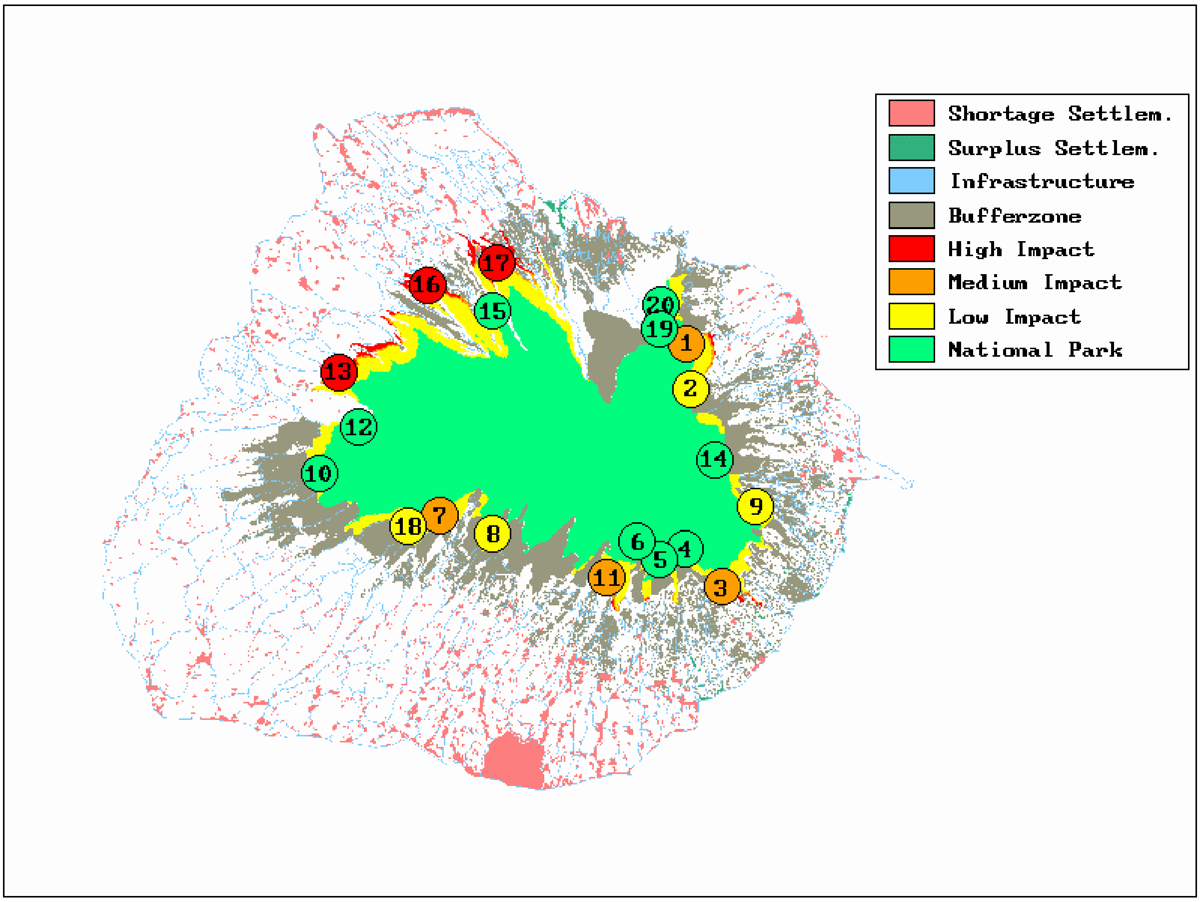

Figure 7. The calculated impact and the location of the samples in the Gunung Gede-Pangrango National Park. Samples in green, yellow, orange and red represent no impact, little impact, moderate impact and severe impact respectively.

Only 2 of the 20 samples, taken in the field, differ substantially from the calculated results. At the location of sample nr. 7, very recent agricultural activities close to the National Park boundaries. probably resulted in an increased impact on the forest. Sample 15 was expected to have little impact, but during the survey no impact was observed. This might be due to the fact that the bordering area was private and strictly prohibited to local people without a permit.

Table 6. Location of the samples taken during the field survey and the model results for the year 1992 and comparison of the results

	No impact	Little	Moderate	Severe
Field-survey Result	4, 5, 6, 10, 12 14, 15, 19, 20	2, 8 9, 18	1, 3 7, 11	13, 16, 17
Model Result	4, 5, 6, 10, 12 14, 19, 20	2, 7, 8 9, 15, 18	1, 3 11	13, 16, 17

Comparing the observed impact of the 20 field-samples with the calculated impact, shows that the figures do not differ much. Therefore, it is assumed, that the results of the model (the expected impact of fuelwood collecting on the natural forest) are reliable enough to be used for simulation purposes.

4. Sensivity Analysis of the Fuelwood Model

The sensivity analysis helps to identify parameters that strongly affect model output and that, therefore, must be estimated with great care. Most sensivity analyses of complex biophysical models involve changing one parameter at a time. The sensivity analysis indicates a "robust" model when small changes in input parameters result in small changes in model output (Swartzman and Kaluzny, 1987).

4.1 Methodology

A sensitivity analysis was conducted by changing each parameter value by +/- 10% and +/- 50%. The sensivity of the model results (the total amount of fuelwood shortage in the Cibodas Biosphere Reserve) for the parameter examined, was classified

Table 7. The sensivity classes used

Parameter changes of +/- 10% and +/- 50% in their values		
+/- 10% change result change (%)	+/- 50% change result change (%)	Sensitivity of the model
0 – 1.0	0 – 5.0	Extreme little
– 2.5	5.0 – 12.5	Very little
2.5 – 5.0	12.5 – 25.0	Little
5.0 – 10.0	25.0 – 50.0	Moderate
10.0 – 25.0	50.0 – 125.0	Much
25.0 – 50.0	125.0 – 250.0	Very much
50.0 – 100.0	250.0 – 500.0	Severe

The research priority for the parameters examined is based on the effect of a certain parameter on the model result If the effect of a parameter is low, research priority is low as well, if the effect of a parameter is high, research priority is high unless detailed research data concerning that parameter is already available.

4.2 Sensivity of the parameters used for the Cibodas Biosphere Reserve

The parameters, used in the Cibodas fuelwood model, are based on existing literature and or research in the field. A sensitivity analysis has been conducted to estimate the effect of the different parameters on the calculated fuelwood shortage.

Table 8. Results of the sensivity test of the used parameters for the Cibodas fuelwood model

Parameters used	% change +/- 10%	Impact +/- 50%	Sensitivity of the model
AVAILABILITY			
Fuelwood production values	10.4	14.5	Little to moderate
DEMAND			
Fuelwood consumption/capita	13.8	59.4	Much
Fuelwood consumption rate	4.6	5.5	Very little to little
ACCESSIBILITY			
Of the different road types	6.7	7.7	Very little to moderate
Of the different land-use types	2.6	3.7	Very little
Bufferzone functionality	0.9	6.7	Extreme – to very little
According to slope steepness	1.0	8.7	Extreme – to very little

The basis quantity of available data on which the parameter value has been established and the priority for further research of that specific parameter are indicated in table 9.

Table 9. Results of the sensivity test of and research priorities for each parameter

Parameters used	Sensitivity of the model	Avail. data	Research priority
AVAILABILITY			
Fuelwood production values	Little to moderate	++	-
DEMAND			
Fuelwood consumption/capita	Much	++	-
Fuelwood consumption rate	Very little to little	++	-
ACCESSIBILITY			
Of the different road types	Very little to moderate	+/-	+
Of the different land-use types	Very little	+/-	+
Bufferzone functionality	Extreme – to very little	-	-
According to slope steepness	Extreme – to very little	-	-

According to the results of the tests, the fuelwood production values for each different land-use type **and** for the fuelwood consumption per capita are the most sensitive parameters. Both are a result of extensive literature studies and field surveys and therefore assumed to be quite reliable. The fuelwood consumption rate (between household fuelwood use and the fuelwood use for small industries and export) has little influence on the final model output. The accessibility has very little to moderate influence on the model results. The values are based on a survey done by Mannathoko et al., 1990. The bufferzone functionality and the slope steepness are based on very limited data. Their influence on the model output is little.

The most sensitive parameters in the Cibodas fuelwood model are studied intensively. It is of great importance that these parameter values are regularly surveyed and if necessary updated. The output of the model is very much depending on the reliability of these parameters.

5. Simulations in the Cibodas Biosphere Reserve

All kinds of management options and combination of options are possible and by running simulations, the model will present the expected outcome in a spatial representation, together with the statistical data of to each spatial entity. It is up to the user of the model to decide which management option (or combination of management options) will be most appropriate.

5.1 Simulation possibilities

The procedure to change maps, tables or factors needed for running a desired simulation is basically the same as for updating the model. The user can run any scenario for any year and when the new calculations are finished, the expected result of that specific scenario will be calculated. An overview of the possible options is given below:

Availability

- maps: landcover/use
- factors: fuelwood production per landuse type

Demand

- maps: settlements
- tables: population statistics
- factors: population growth
  - fuelwood consumption / capita
  - fuelwood consumption rate / area

Accessibility

- maps: infrastructure
    - landcover/use
- factors: travelling speed using infrastructure
    - travelling speed in the field
    - slope correction
    - protective buffer function

5.2 Management Decisions (Simulations) and the Expected Response

During the regional workshop on "Geo-Information systems for Natural Resource Management of Biosphere Reserves", d.d. 14 - 17 June, 1993 in Bogor, Indonesia, the participants analyzed the problems occurring in the Cibodas Biosphere Reserve and discussed possible management options, to solve these problems. By making use of the developed fuelwood model several simulations were done. The results are discussed below.

The result of the model refers to the year 1992. In total the fuelwood available from the buffer zone and the transition zone is 97852 m^3, but the total demand for fuelwood by the people living in the transition zone of the Cibodas Biosphere Reserve is estimated to be 421196 m^3, resulting in a shortage for fuelwood of 323344 m3. Only 7 of the 156 desa's have a fuelwood surplus (e.g., Cibeureum 1082 m^3, Sarampad 91 m^3, Kemangman 612 m^3, Bunikasih 545 m^3, Tegalega 433 m^3, Kebonpeut 211 m3 and Gekbrong 587 m^3). The areas of the park with severe damage from illegal fuelwood collection are mainly in the northwestern, northeastern and southeastern part of the national park,.where the national park is not or little protected by a buffer zone.

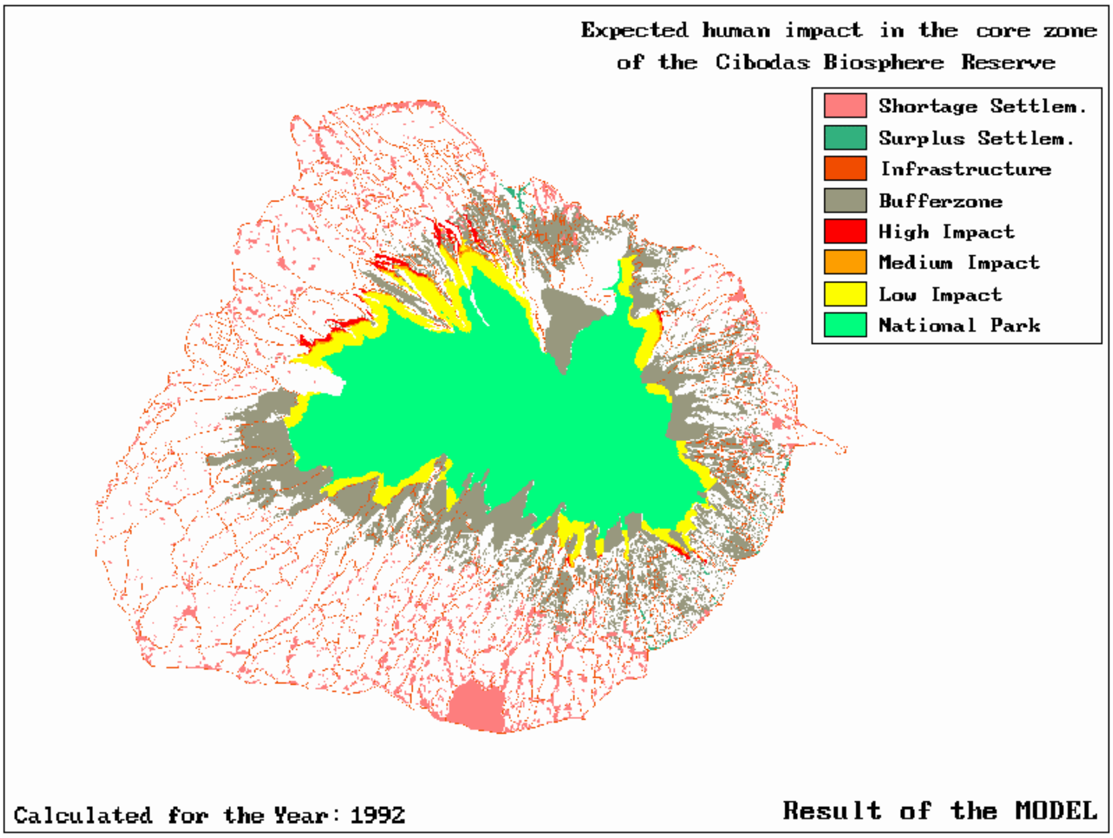

Figure 8. The spatial result of the model, based on the situation in the year 1992. Black represents severe impact, dark grey less

impact and medium grey no impact in the National Park. The light grey areas surrounding the National Park is the buffer zone area (production forest or tea estate). The light grey areas in the transition zone are settlements or represents infrastructure.

Simulation 1:
In the first simulation it is assumed that no specific management actions are taken to improve the fuelwood situation, which means that all basic data remains unaltered (same infrastructure, land use, fuelwood consumption per capita etc.). Figure 9 presents the predicted situation in the year 2002, i.e. after 10.

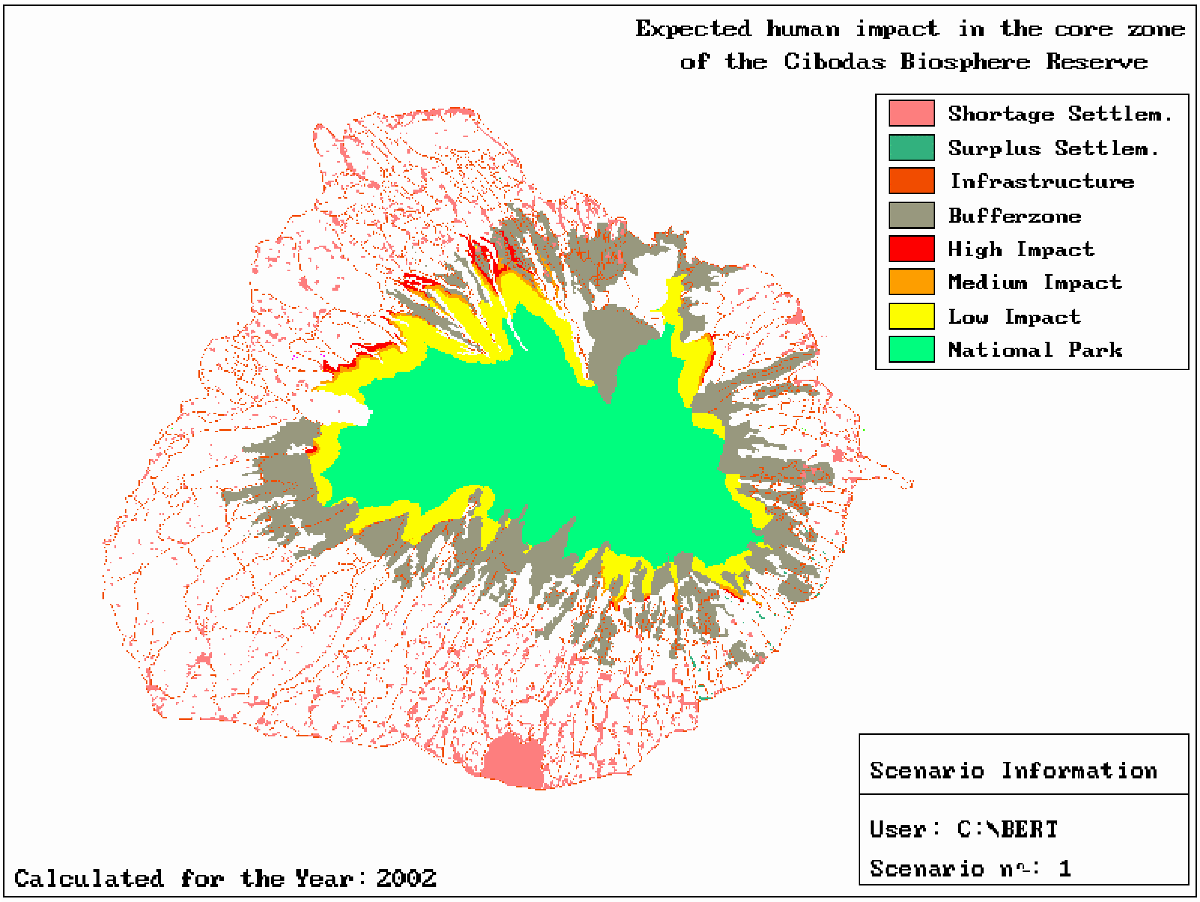

Figure 9. **Spatial result of simulation 1 without specific management actions for the year 2002, with severe impact especially where the accessibility is high (no surrounding buffer zone) and/or human settlements or agricultural activities close to the National Park.**

Figure 9 clearly shows that there will be a considerable increase of the pressure on the National Park. There will be an increase of fuelwood shortage from 323344 m^3 to 505354 m^3 per year, due to the increasing demand for fuelwood (from 421196 m3 to 603206 m^3, which is, in turn caused by the high population growth (3.1%). Landuse (with a total production of 97852 m^3 per year), settlement location and accessibility were assumed not to change

Simulation 2:
For better protection of the National Park, it was suggested to surround the whole National Park with a buffer zone e.g. production forest or tea estates, where existing roads have to be closed for the public. Besides a better protection, it might also increase the production of (secondary) fuelwood (production forest and tea estates have an estimated production of respectively 2.2 and 1.2 m^3/ha per year versus a production of dryland vegetables or cashcrops of 0.7 m^3/ha per year). Furthermore when unproductive production forest or abandoned tea estates border on the National Park, they have to be changed into functional buffer zone as well, because their actual status invites local people to cross these areas into the National Park. Unfortunately these areas have an estimated fuelwood production of 7.5 m^3/ha per year. The result of this simulation is presented in figure 10.

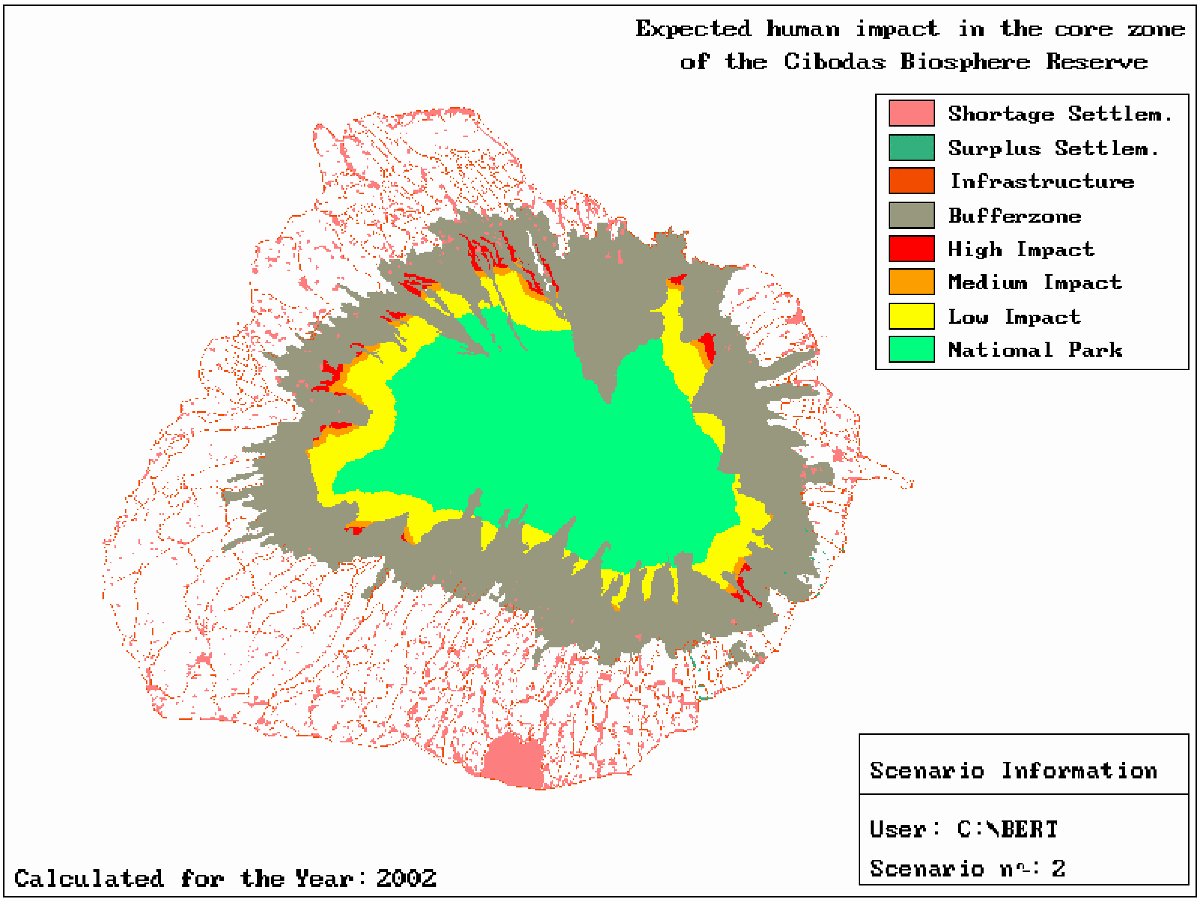

Figure 10. The result of simulation 2 for the year 2002, if the whole National Park is surrounded by a functional buffer zone.

The estimated fuelwood production decreased from 97852 m^3 to 76904 m^3 per year for the entire Cibodas Biosphere Reserve, because large areas of unproductive forest have been converted to production forest. Demand remained the same as for 2002 (603206 m^3 per year).

The result is not satisfactory at all. The total pressure increased little compared to the result of the first simulation for the year 2002 (fuelwood shortage changed from 505354 m^3 to 526302 m^3 per year), and the location of the impact changed, which is mainly due to the changed accessibility of the National Park.

Simulation 3:
Another possibility to improve the situation is to look at the fuelwood **production** side of the ecosystem. Cash crops are popular landuse types at the moment, but with very low fuelwood production, estimated on 0.7 m^3/ha per year. The change from annual cash crops to for instance perennial crops, with a comparable marketing value, but much higher fuelwood production, around 4.0 m^3/ha per year, will reduce the impact on the National Park. The result is shown in figure 11.

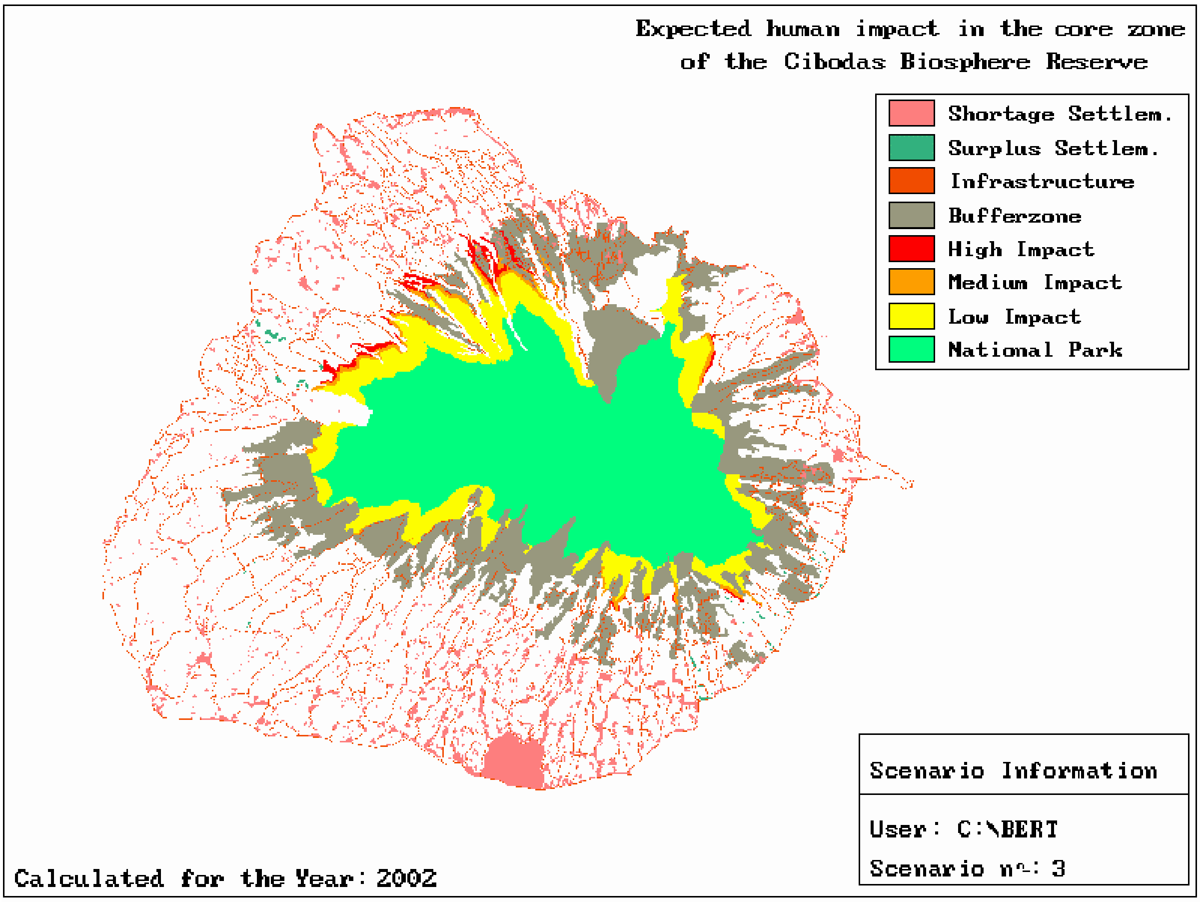

Figure 11. The result of simulation 3 for the year 2002, with annual cashcrops replaced by perennial crops (fuelwood production of 4.0 m^3/ha per year).

The change from annual cashcrops to perennial crops is not only difficult matter, but the influence on the total pressure is also little (from 505354 m3 to 475597 m^3), a reduction of about 6 percent only. The spatial distribution of the pressure on the National Park has hardly changed. Therefore, it may be concluded to look for alternative management options, which are less difficult to implement and above all, give a greater decrease in impact on the National Park.

To increase the production of fuelwood, the most appropriate and efficient way is introduction of fuelwood plantations. The production of fuelwood plantations is about 17.5 m^3/ha per year. But to fulfil at least 50% of the local need in the year 2002 (603206 m^3 per year), at least 17.000 ha in the transition zone should be converted from agricultural landuse to fuelwood plantations.

The whole transition zone of the Cibodas Biosphere Reserve is about 45.000 ha, which means that about 37% of the whole transition zone should be converted to fuelwood plantations, to fulfil only 50% of the local need. This seems a very unrealistic management option.

When comparing the amount of fuelwood produced in the Cibodas Biosphere Reserve with the local demand for fuelwood, the difference is great. The demand is about six times greater than the production. Therefore, the next simulations attempt to reduce the demand for fuelwood.

Simulation 4:
To reduce fuelwood **consumption** in the Cibodas Biosphere Reserve (0.6 m^3 per capita), one might have to resort to selling kerosine for a very low (subsidised) price, introducing or expanding other alternative energy sources (electricity) or introducing more efficient stoves for cooking and heating, etc (RADEP, 1986, Smiet, 1990, Suhaedi, 1992). According to the participants of the workshop a fuelwood consumption of 0.3 m^3 per capita realistic. The result is presented in figure 12.

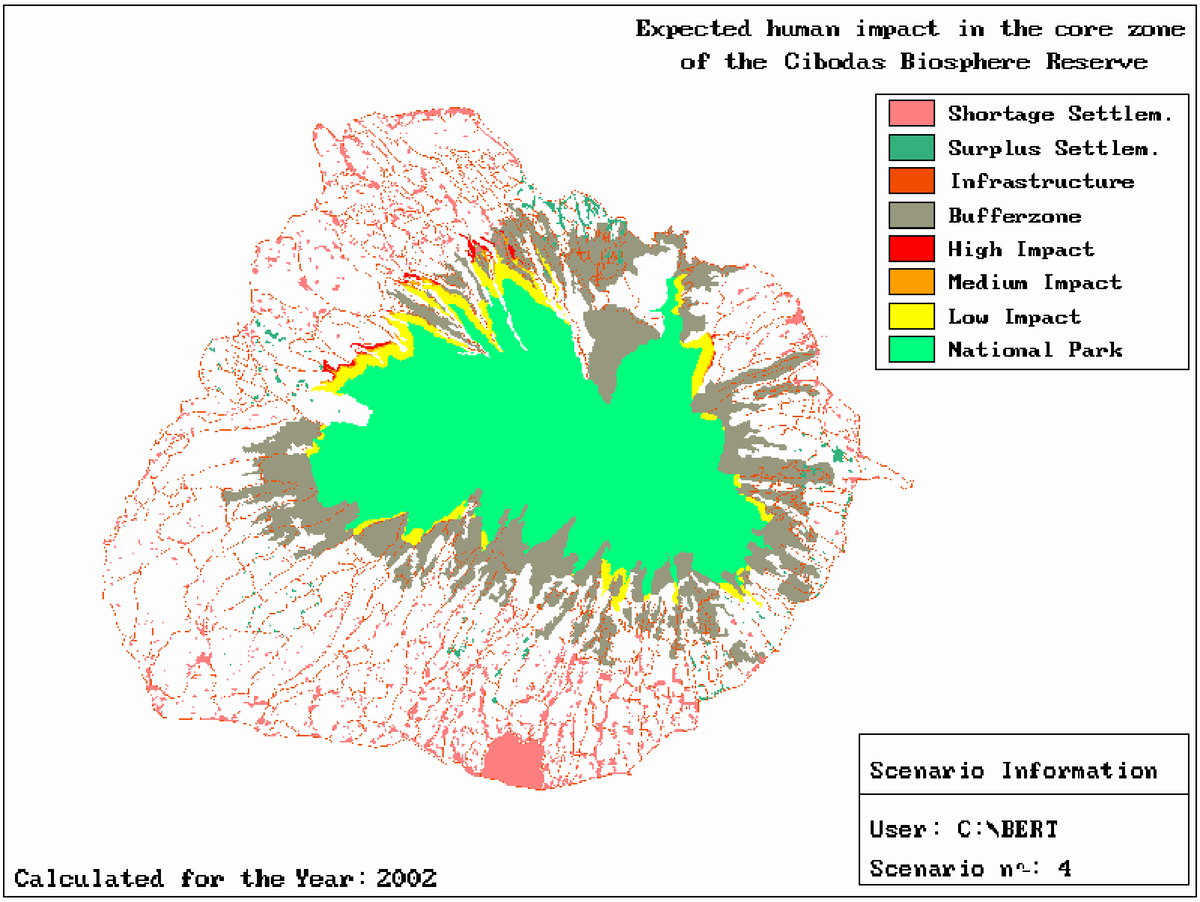

Figure 12. The result of simulation 4 with the fuelwood consumption in the year 2002 brought back from 0.6 to 0.3 m^3 fuelwood per capita.

In this simulation the demand for fuelwood declined, from 603206 m^3 to 301603 m^3 per year for the whole Cibodas Biosphere Reserve. The total shortage fuelwood is estimated to be 203751 m^3 per year, a reduction by almost 60 percent. Also spatially the impact on the National Park is strongly reduced and mainly concentrated in the north western part of the core zone. If fuelwood consumption can be curbed to 0.3 m^3 per capita, the development of an ecosystem that can survive the fuelwood crisis is really going in the right direction. It is clear that this item deserves attention and priority.

Simulation 5:
A maximum decrease of fuelwood consumption, which is almost beyond reality, is obtained by reducing the fuelwood consumption per capita from 0.6 to 0.3 m^3/yr., together with a decrease of population growth from 3.1% to 2%. This was under assumption that all small home industries are going to use alternative energy instead of fuelwood. The result is shown in figure 13.

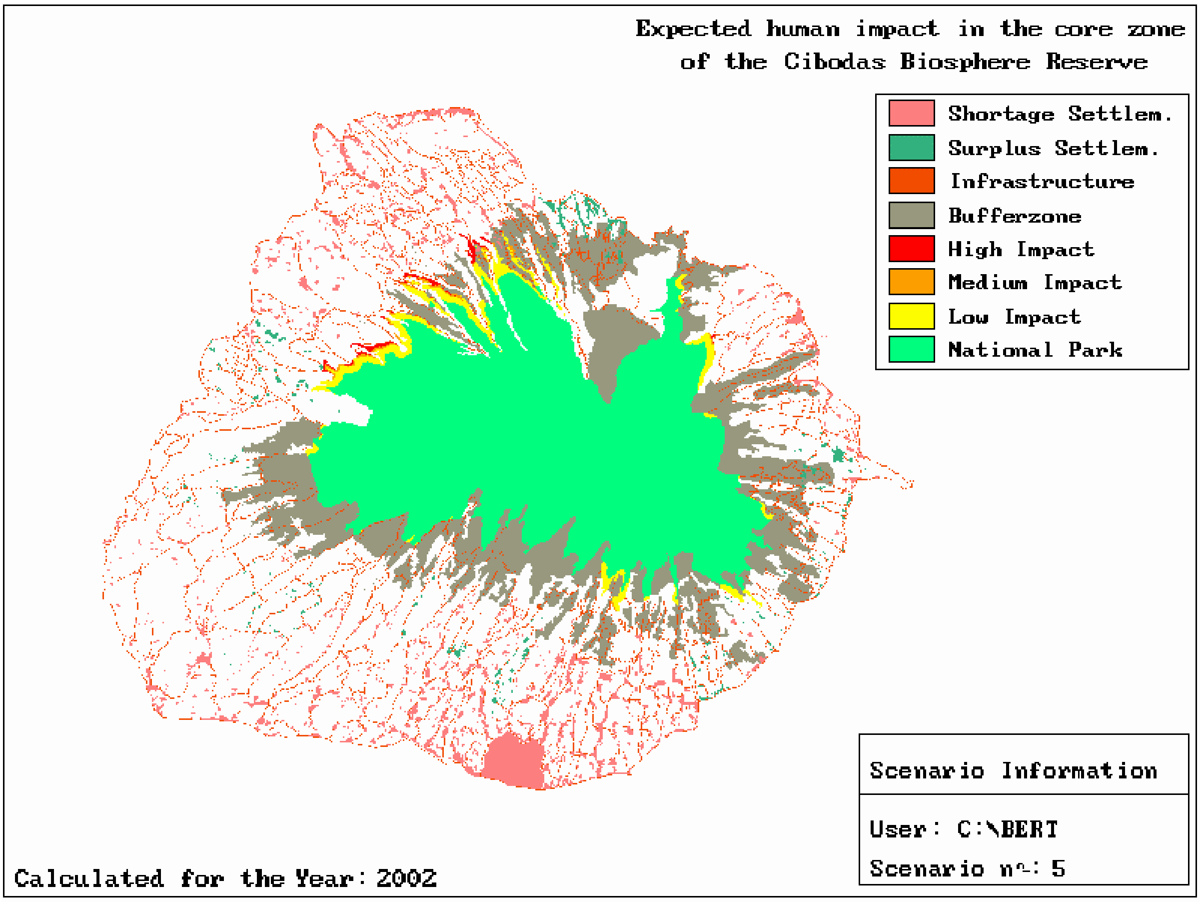

Figure 13. The result of simulation 5 for the year 2002, population growth assumed down to 2%, fuelwood consumption of 0.3 m^3/ha and small home industries entirely depend of alternative energy sources.

This brings the need of fuelwood back from 603206 to 246192 m^3 per capita, a decrease of about 60 %. The impact, on the Biosphere Reserve is limited to certain specific areas, especially the north-west, and is in the whole Reserve reduced from 505354 m^3 to 148340 m^3, a reduction of about 70 %. The model is even able to provide statistical data per smallest administrative unit (desa). Particularly in the northwestern part, the desa's Lembahduhur (-2525 m3), Cimande (-1139 m^3), Cileungsi (-1138 m^3) and Tangkil (-1107 m^3) need special attention. In the northern part the desa's Citeko (-1825 m^3) and Sukagalih (-1657 m^3), in the east east the desa's Ciherang (- 1849 m^3), Cipanas (-1695 m^3) and Cipendawa (-1653 m^3), and south the desa Krawang (-2149 m^3) are still quite short in fuelwood.

From this it may be concluded, that the main emphasis in developing satisfactory management options will be on a combination of management measures. If only 5% of the total transition zone (about 2250 ha) is converted to fuelwood plantation (stimulated by the recently started and subsidised 'regreening programme'), still 563831 m^3 is needed in the year 2002. If fuelwood consumption can be reduced from 0.6 to 0.3 m^3 per capita (local need 301603 m^3 per year), still 262228 m^3 is needed. If population growth can be brought back to 2% as well and the small home industries change completely to alternative energy (simulation 6), the need is still 108965 m3. This means for example that at least 6000 ha of additional fuelwood plantations are needed to fulfil meet the demand.
For total protection of the National Park an additional 108965 m^3 fuelwood has to come from other sources e.g. from other less densely populated areas. Furthermore, the manager is now aware of the locations, which are the most susceptible to degradation, by illegal fuelwood collection. He can propose other, more selective and small scale management activities even to protect these areas against degradation.

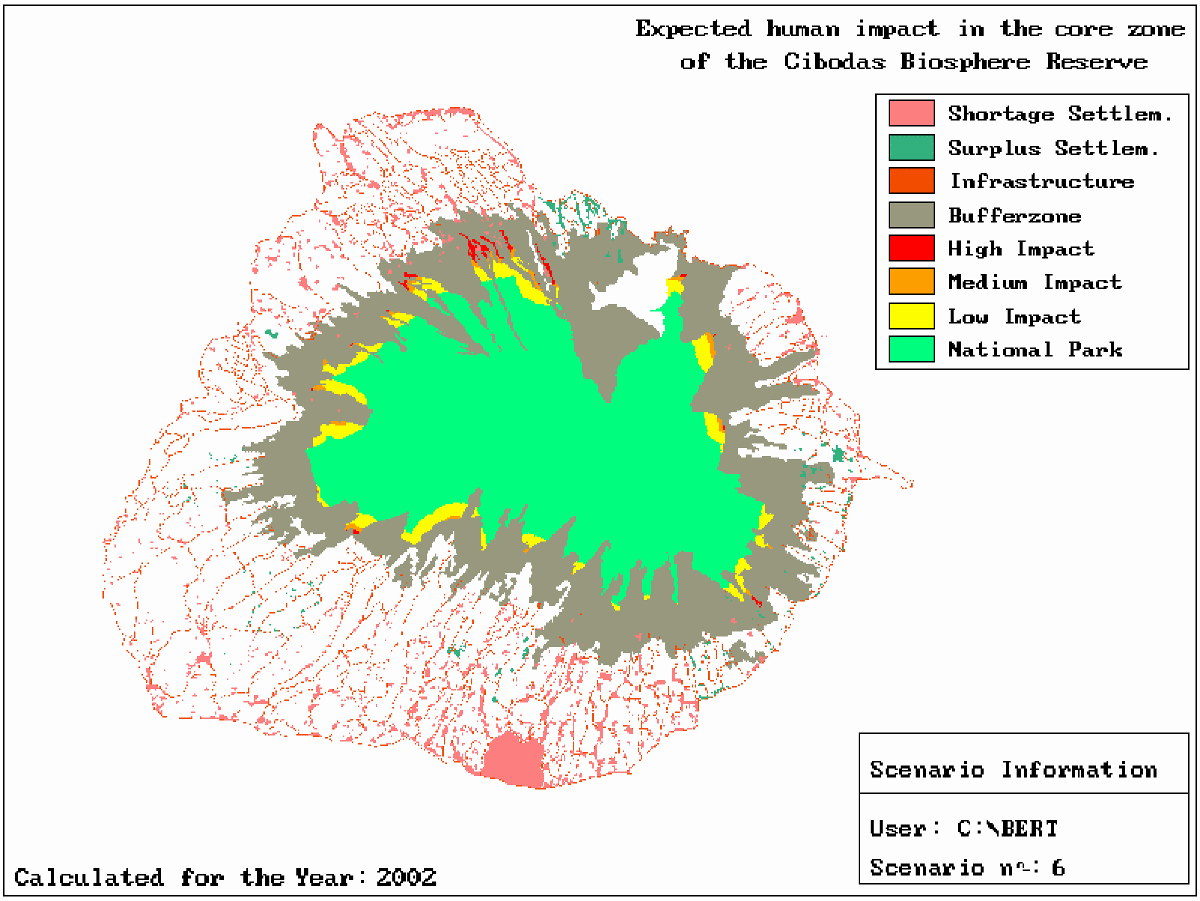

Figure 14. The spatial result of simulation 6 for the year 2002, where both the population growth went down to 2%, the fuelwood consumption decreased to 0.3 m^3/ha, small home industries changed to alternative energy sources and the buffer zone has been expended near previous endangered areas of the National Park.

Simulation 6:
When expanding the fragmented buffer zone in areas, where impact is still great (in simulation 4 or 5), together with the maximum decrease of fuelwood consumption (as in simulation 5), the calculated impact is still the same, only differently localised. The result is shown in figure 14. This scenario suggests that fuelwood production changes from 97852 m^3

to 84318 m^3 per year, due to conversion of agricultural land to buffer zone, while the demand is still the same (246192 m^3 per capita); the shortage was still 161874 m^3 per year. Again for most of the desa's the fuelwood values (production and shortage) have changed as well.
When considering the fuelwood shortage for each desa and looking at the percentage of each landuse type (statistical output), with the total acreage known (statistics belonging to each administrative unit), it is possible to estimate the influence of, changing certain landuse types (e.g., annual cash crops with a fuelwood production of 0.7 m^3/ha per year) to more fuelwood producing landuse types (e.g., perennial cash crops with a 4.0 m^3/ha fuelwood per year). This increases the production with 3.3 m^3/ha (0.7 m^3 => 4.0 m^3).

This calculation shows the possibility for the user to estimate, by making use of both the spatial (qualitative) data and statistical (quantitative) data, to what extent certain management options are needed, what their influence will be, etc. It is clear from above, that the change from annual cash crops to perennial crops with a much higher fuelwood value is still not contributing enough to meet demand. Desa's with very little annual cash crops, like Lembaduhur, Cimande and Cileungsi, will of course, increase fuelwood production very little. Therefore, other alternatives have to be found for these Desa's. On the other hand, for desa's like Kopo, Cipanas and Cipendawa the proposed landuse change will have a much more positive effect on the fuelwood production, although not entirely sufficient. In these cases the proposed landuse change is an option, but only in combination with other management options as well.

Table 10. The result of the effect of landuse change in fuelwood shortage for some desa's with still considerable shortage for fuelwood

Desa	A fuelwood shortage (m^3/year)	B Total acreage (ha)	C Annual cash crops (% of B)	D Acreage cash crops (ha)	E Increase fuelwood (3.3 x D)
NW-area					
Lembaduhur	2490	384	1	4	13
Cimande	1218	282	3	8	26
Cileungsi	1259	332	2	7	23
Penciwati	1338	1122	6	67	221
Citapen	1406	501	2	10	33
Cibedung	1259	467	5	23	76
N-area:					
Kopo	3352	686	17	117	386
Sykagalih	1599	385	4	15	50
Citeko	2266	512	9	46	152
E-area:					
Cipanas	1839	816	26	213	703
Ciherang	1992	655	12	79	261
Cipendawa	1667	717	16	115	380
S-area:					
Langensari	1365	784	4	31	102
Sudajayagirang	1161	549	10	55	182
Krawang	2763	777	5	39	129
Undrusbinang	1034	242	4	10	33

One of the management possibilities left is strict protection of the National Park in these areas so as to force the local people to buy fuelwood from elsewhere or to use alternative energy sources. To stimulate localized fuelwood plantations can help solving some of the problem. Many more possibilities can be considered, but it is upto the manager or planner to decide, which option is the most effective and feasible.

5.3 Simulation of the Cibodas Biosphere Reserve in practice

Summarizing, the Cibodas "fuelwood model" can provide managers and other decision makers with information, which might lead to decisions, that are adequate for the near future. The examples shown are simulations running over a 10 years time interval. Proposed management plans often cover a 5 or 10 years time interval. In fact the model is able to run for any time interval, specified by the user. Some of the solutions, as summarized in table 11, might not be completely satisfactory in 5 or 10 years. However, it is also not realistic to attempt to solve fundamental problems such as reducing high population growth, or to change traditional land use in such a short time. In such cases it is already useful to have at least an indication in what direction and to what extent certain management options will influence the development of the ecosystem in question.

Table 11. Summary of the results of the Cibodas fuelwood model and the results of the simulations carried out to reduce the impact on the National Park

Management actions	Fuelwood shortage (m^3)	Fuelwood prod. (m^3)	Fuelwood demand (m^3)	Result (%)
Model: Actual situation	323344	97852	421196	n.a.
Simulation 1: No action	505354	97852	603206	n.a.
Simulation 2: Extending bufferzone	526302	76904	603206	- 4
Simulation 3: Introd. Perennial crops	475597	127609	603206	+ 6
Simulation 4: Fw. Cons. Reduced to 0.3	203751	97852	301603	+ 60
Simulation 5: Sim. 4 + popgr. 2.0 + no ind.	148340	97852	246192	+ 71
Simulation 6: Sim. 2 + sim. 5	161874	84318	246192	+ 68

Running many simulations over a period of, for instance, 10 years, suggests that the impact on the National Park can not be completely reduced to zero when using realistic options. But with development going in the right direction, the situation may become satisfactory after a 25 years or more, provided that the population growth has indeed reduced to 2% or that alternative energy really has become cheap and popular.

The results of certain simulations will give the user a good impression of those management options, which are likely to influence the development in the ecosystem in a desired or not desired direction. The results will also indicate what management option will have a strong (e.g., the fuelwood consumption, population growth) or just little influence (e.g., fuelwood plantations, buffer zone) on the ecosystem. Therefore, the results from the Cibodas fuelwood model will also serve as a guideline for decision makers, to emphasize on those management options that will lead to the desired situation as soon as possible.

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