Nepal

REDD - Forestry and Climate Change Cell

Development of a Measurement, Reporting and Verification (MRV) System for Emissions and Removals

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Working Document N.__

WISDOM* Nepal
and contribution to MRV

*** Woodfuel Integrated Supply/Demand Overview Mapping**

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Acronyms and abbreviations

ad	Air-dry, assuming 12 % moisture content
AGB	Aboveground Biomass
CBS	Central Bureau of Statistics
DEB	DendroEnergy Biomass (woody aboveground biomass less stump and twigs)
DTM	Digital Terrain Model
ESA	European Space Agency
FAO	Food and Agriculture Organization of the United Nations
FD	Forestry Department
fNRB	fraction of Non Renewable Biomass (i.e. non sustainable fraction)
FRA	Forest Resources Assessment
Fw	Fuelwood
GACC	Global Alliance for Clean Cookstoves
GDB	Geodatabase
GIS	Geographic Information System
HH	Household
ICIMOD	International Centre for Integrated Mountain Development
kt	kilo tons ('000 metric tons)
LC	Land Cover
MAI	Mean Annual Increment
MPFS	Master Pland of the Forestry Sector
MRV	Measurement, Reporting and Verification of the UN-REDD Proghramme
NLSS	Nepal Living Standars Survey
od	Oven-dry, at 0% moisture content
PPS	Probability Proportional to Size
RWEDP	Regional Wood Energy Development Programme (FAO Project)
VDC	Village Development Committee
WCMC-IUCN	World Conservation Monitoring Centre - International Union for the Conservation of Nature
WECS	Water and Energy Commission Secretariat
WHRC	Woods Hole Research Centre
WISDOM	Woodfuel Integrated Supply/Demand Overview Mapping

1. INTRODUCTION

In Nepal, fuelwood represents 96 % of the total wood annually harvested (from forest, other wooded lands and farmlands) and it produces over 70% of all energy consumed in all sectors. These facts place fuelwood at the very core of the man-forest relation in Nepal. It is also evident that its role on the pressure exerted on forests and on woody biomass resources in general is of paramount importance.

Nepal has abundant woody biomass resources in its forests, woodlands and farmlands, whose annual sustainable growth potential exceeds the demand for fuelwood of the Country but demand and supply potential are unevenly distributed and so is the pressure on the resources, resulting in excessive harvesting in certain areas while other areas remain untapped. While sustainable harvesting with adequate rotation periods does not permanently reduce the biomass stock and does not diminish the productive potential of the forests, unsustainable harvesting, i.e. excessive and repeated wood extractions, are cause of forest degradation with loss of biomass stock and diminished regrowth capacity.

In order to identify the areas where fuelwood extraction may be higher than the sustainable productivity, and thus cause of forest degradation, it is necessary to analyze the spatial distribution of fuelwood demand and of the supply sources, which is the scope of the Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) methodology. WISDOM, which has been implemented in many countries and in various planning contexts, is here applied in support of the MRV System for the quantitative and spatial-explicit definition of the risk of forest degradation due to the current demand for fuelwood.

1.1 SCOPE WISDOM NEPAL IN THE CONTEXT OF REDD MRV SYSTEM

Scope of this activity, carried out in the framework of the MRV Project, is to contribute to the estimation and spatial distribution of the risk of forest degradation induced by excessive fuelwood extractions. At the same time, WISDOM Nepal is a tool that can strengthen wood energy planning in general, enhancing inter-sectoral and interdisciplinary decision making processes and supporting strategic planning and policy formulation.

The objectives of this activity are to (i) analyze the sustainable supply potential and the demand for woodfuels in Nepal, and produce spatially explicit results on supply/demand balance for local and commercial woodfuels use and identify surplus and deficit areas through the WISDOM model, (ii) provide estimates of the sustainable /unsustainable harvesting related to wood energy demand.

The analysis is intended as interdisciplinary and cross-sectoral, including forestry, energy, territorial and socio-economic components, as is typical for WISDOM analyses. Given the large variety of data sources integrated in the analysis, the limited time and resources available and the methodological scope of the project, the analysis is based entirely on existing information.

1.2 MAIN FEATURE OF THE WISDOM METHOD

The methodological approach is based on the following three fundamental characteristics of wood energy systems:

Geographical specificity. The patterns of woodfuel production and consumption, and their associated social, economic and environmental impacts, are site specific (Mahapatra and Mitchell, 1999; FAO/RWEDP, 1997; FAO, 2003d).

Heterogeneity of woodfuel supply sources. Forests are not the sole sources of woody biomass used for energy. Other natural landscapes, such as shrublands, as well as other land uses –farmlands, orchards and agricultural plantations, agroforestry, tree lines, hedges, trees outside forest, etc. – contribute substantially in terms of fuelwood and, to a lesser extent, of row material for charcoal production.

User adaptability. Demand and supply patterns influence each other and tend to adapt to varying supply patterns and resource availability. This means that quantitative estimations of the impacts that a given demand pattern has on the environment are very uncertain, and should be avoided (Leach and Mearns, 1988; Arnold et al., 2003).

In order to cope with the various dimensions of wood energy, the Wood Energy Programme of the FAO Forest Products Service has developed and implemented the **Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) methodology**, a spatially-explicit planning tool for highlighting and determining woodfuel priority areas or woodfuel hot spots (FAO, 2003). WISDOM is the fruit of collaboration between FAO's Wood Energy Programme and the Institute of Ecology of the National University of Mexico. At national level, the WISDOM approach has been implemented in Mexico (FAO, 2005), Slovenia (FAO, 2004a), Senegal (FAO, 2004b), Castilla y Leon (Spain), Italy, Croatia, Central Africa Republic, Mozambique, Argentina, Rwanda, Peru, Chad, Sudan and it's currently being implemented in Nepal. At subregional level, WISDOM was implemented over the eastern and central Africa countries covered by the Africover Programme (FAO, 2005g) and over the countries of South East Asia (FAO, 2007).

Currently, WISDOM is applied (and further developed) in the Project "Geospatial Analysis and Modeling of Non-Renewable Biomass: WISDOM and beyond" carried out by Yale University and Mexico University UNAM for the Global Alliance for Clean Cookstoves (GACC). Scope of the GACC project is to estimate and map the non-renewable fraction of the woody biomass used for energy at sub-national level on all tropical countries.

WISDOM is meant to create a spatially-explicit knowledge base on supply and demand of woody (and non-woody) biomass for energy and thus to serve as a planning tool for highlighting and determining **priority areas** of intervention and to **focus planning options**. The result of the wall-to-wall supply/demand balance analysis is then used as starting point for the delineation of the necessary supply areas for existing or hypothetical commercial consumption sites.

WISDOM features:

- **Geo-referenced data bases.** A core feature of the approach is the spatial base on which the data is framed. The analysis and presentation of results for all modules is done with the help of a Geographic Information System (GIS).
- **Minimum administrative and spatial units of analysis.** The spatial resolution is defined at the beginning of the study, on the basis of the desired level of detail (national study, regional study) and as constrained by the main parameters or proxy variables that will be used to "spatialize" the information. In most cases the basis for the definition of the administrative level of analysis is provided by the existing demographic data (i.e. census units), which represents the most detailed sub-national structure of a country. The spatial level of analysis (i.e. the size of the pixel in GIS raster data) is usually determined by the mapping detail of the available land use/land cover data.
- **Modular and open structure**. WISDOM consists of modules on demand, supply, integration and woodshed analysis. Each module requires different competencies and data sources and its contents is determined by the data available or, to a limited extent, by the data purposively collected to fill critical data gaps. Once the common spatial base of reporting is defined, each module is developed in total autonomy using existing information and analytical tools and is directed to the collection, harmonization, cross-referencing and geo-referencing of relevant existing information for the area of study.
- **Adaptable framework**. As mentioned previously, the information of relevance to wood energy comes from multiple sources, ranging from census data to local pilot studies or surveys, to projected estimates with unknown sources, and is often fragmented and poorly documented. Proxy variables may be used to "spatialize" discontinuous values. In synthesis, WISDOM tries to make all existing knowledge work for a better understanding of biomass consumption and supply patterns.
- **Comprehensive coverage of woody and non-woody biomass resources and demand from different users**. The analytical framework includes of all sources of biomass potentially available for energy (i.e. fuelwood and charcoal, crop residues, industrial residues, etc.) and all users categories (rural and urban residential; industrial; commercial and public).

The WISDOM methodology may be divided into two sequential stages of analysis:

1 - **WISDOM Base**. This stage includes the analysis over the entire territory of the study area.

2 - **Woodshed[1] analysis**. This second stage of the analysis uses the result of the WISDOM Base to delineate the sustainable supply zone of selected consumption sites. Depending on the scale and objectives of analysis, the selected sites could be all major deficit areas (those that depend on commercial supply chains) or specific urban centers, rural villages and existing/planned biomass plants.

The specific steps of analysis are summarized below while a graphic overview is shown in Figure 1.

WISDOM Base

The application of the standard WISDOM analysis producing supply and demand balance mapping at the local level involves the following main steps (FAO, 2003b).

1. Definition of the minimum administrative *spatial* unit of analysis.
2. Development of the *demand* module.
3. Development of the *supply* module.
4. Development of the *integration* module.
5. Selection of the *priority* areas or woodfuel "hot spots" under different scenarios.

Woodshed analysis

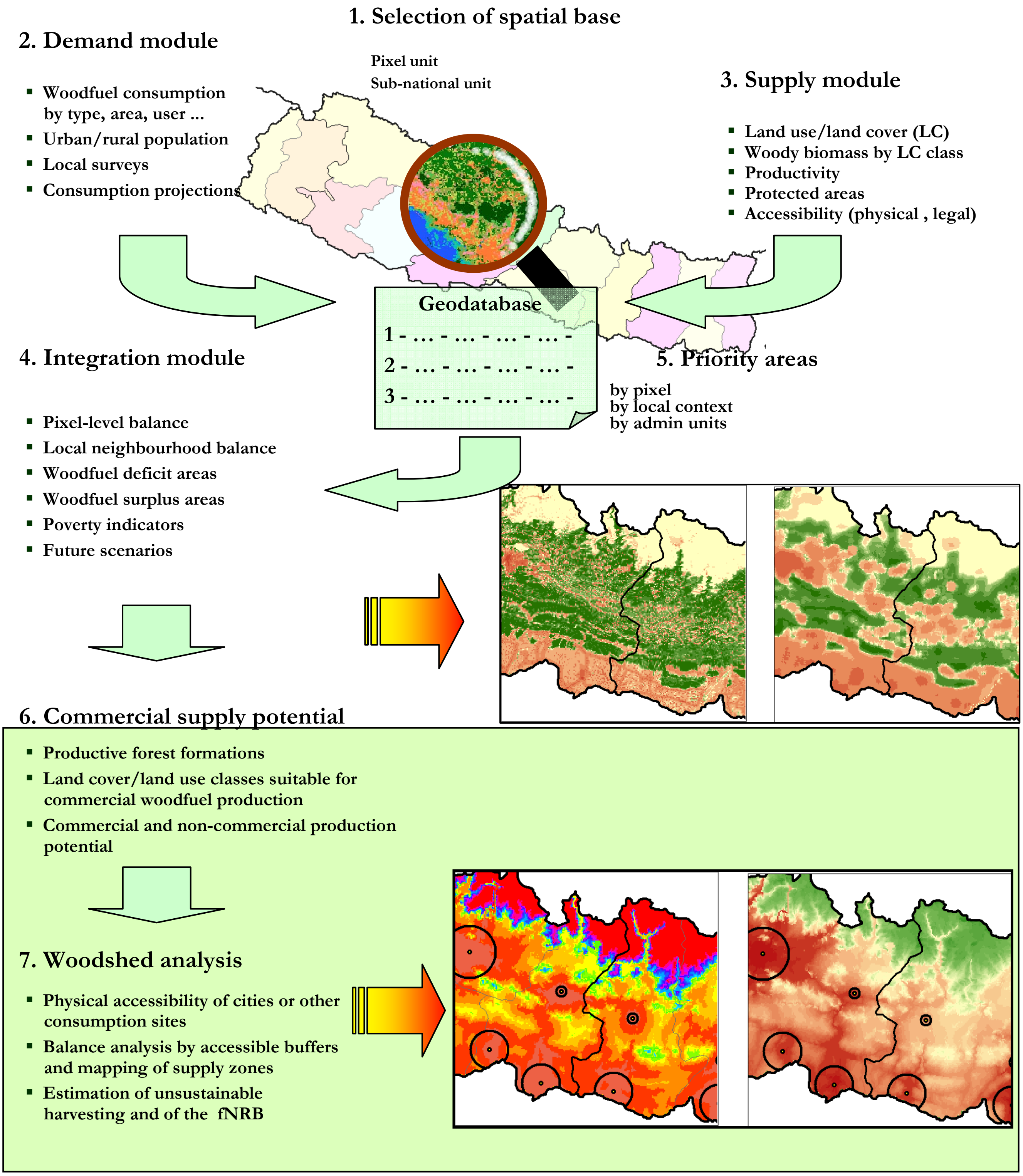
The analysis for the delineation of woodsheds, i.e. supply zones of specific consumption sites requires additional analytical steps that may be summarized as follows.

6. Mapping of potential "commercial" woodfuel supplies suitable for urban, peri-urban and rural markets.
7. Definition of woodshed, or potential sustainable supply zones, based on the level of demand, woodfuels production potentials and physical accessibility parameters.

[1] The term "woodshed" is a neologism inspired by the familiar geographic concept of *water*shed. It is used to indicate the portion of the territory necessary to supply on a sustainable basis the woody biomass needed by a specific consumption site (existing or hypothetical).

FIGURE 1

WISDOM analytical steps. WISDOM Base (steps 1 to 5) and Woodshed analysis (steps 6, 7)



2. WISDOM ANALYSIS

The following Sections describe the steps of analysis undertaken during the development of WISDOM Nepal, following the procedure of analysis summarized in the previous Section.

The work implied the creation of a large amount of digital maps but only the most relevant ones are discussed and shown in this report. The details such as filename and development process of all the thematic maps used and produced during the WISDOM analysis are reported in Annex 6.

2.1 SELECTION OF SPATIAL BASE OF ANALYSIS

2.1.1 Scale and projection

Mapping details:

Projection: Preferred/common projection for Nepal : Modified UTM Central zone 84D (Datum Everest 1830) (single projection for whole country

Cell size of raster layers: 100 meters (1-ha cells)

Administrative units used for population mapping:

Census results are provided down to VDC level (3,986 units) These are be used to map population distribution.

Most published census results related to the saturation of fuelwood in the residential sector (fraction of households using fuelwood) are at District level (75 units). Other sources refer to broader strata that represent aggregations of Districts and rural/urban contexts (ex: CBS NLSS 2010 study).

2.1.2 Reference years of WISDOM analysis

The reference years of the WISDOM analysis is usually determined by the reference years of the selected land cover data. In this case a precise reference date cannot be set. However, since ICIMOD data contributes significantly, the reference year of the Supply Module may be set at 2010.

Concerning the Demand Module, the year of the last demographic census is 2011.

The temporal reference of the WISDOM analysis is therefore **2010-2011**.

2.2 DEMAND MODULE

The goal of the Demand Module is to estimate the current consumption of woody biomass for energy in the various sectors (residential, commercial, industrial and public) and to represent as accurately as possible its spatial distribution. The main thematic layers and processing steps of the Demand Module are presented in the flowchart in Figure 2 and described in the following Sections.

2.2.1 Reference data

Household sector

The main references that may be used for the estimation of the current consumption of woodfuels in the residential sectors include the following:

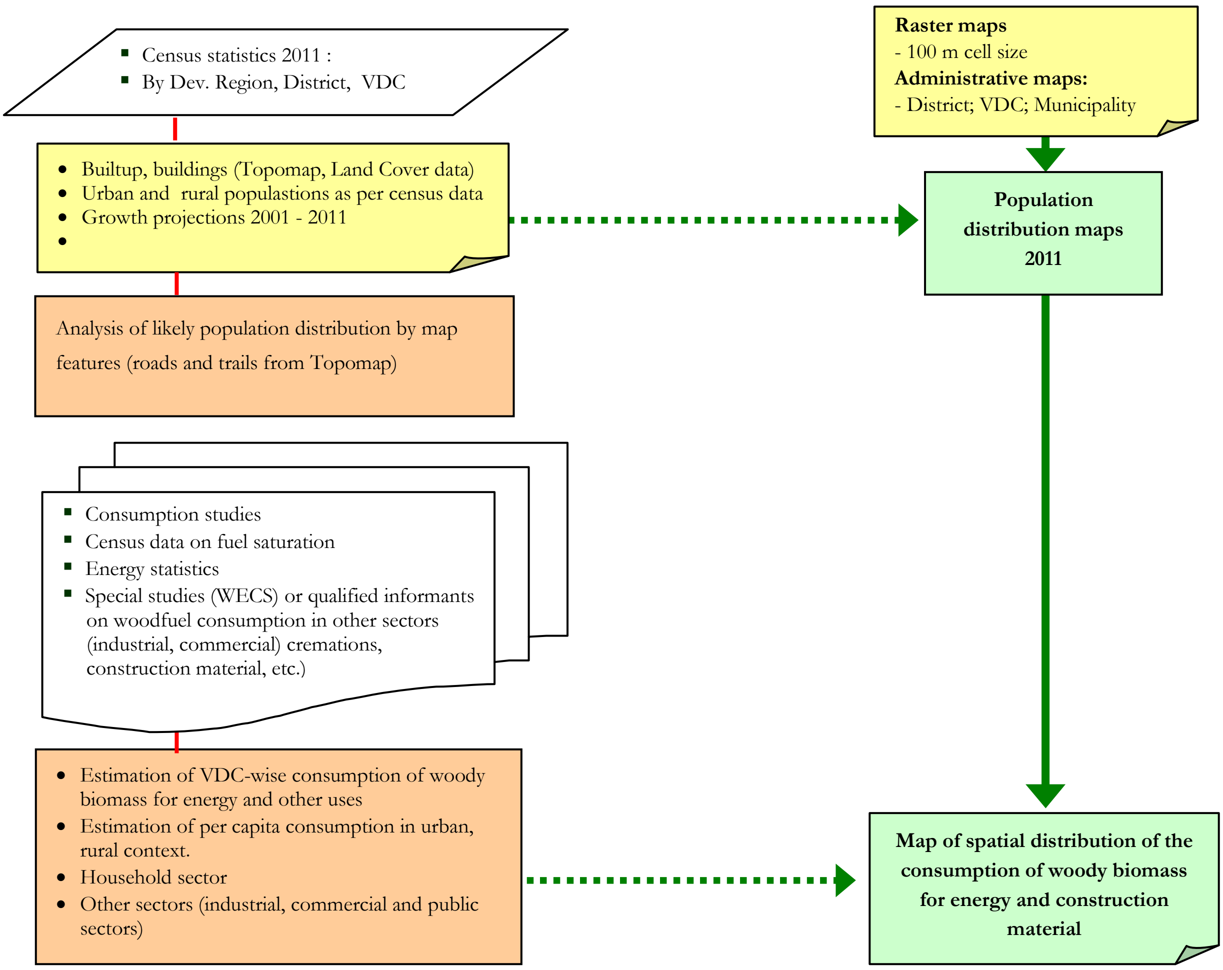
(i) Census 2011 results at District level on the fraction of households using fuelwood as primary cooking fuel in rural and urban areas.

(ii) CBS NLSS 2010 , providing saturation and fuelwood consumption values for rural and urban areas based on 28670 households interviewed divided into 14 strata, as shown in Annex 1.

(iii) Estimates of the quantities consumed by fuelwood users (MPFS 1988, CBS's National Living Standard Survey 2010-2011, and other studies (Fox 1984, Rijal 2002). Annex 1 provides a summary of the per capita consumption values produced by various sources and of the values applied in the present study.

FIGURE 2

Demand Module. Flowchart of main analytical phases. Input data: cartographic (yellow); statistical (white); estimated variables (orange); thematic map outputs (green).



The household sector consumption is estimated to be **9,885,105 ad tons** (including conventional and marginal fuelwood).

Other uses of woody biomass at household level include cremations and the use of construction material.

Cremations

The cremation of the dead is a common practice among Hindus, with significant consumption of fuelwood. There are no statistics available about the fuelwood consumed in cremations ceremonies and therefore the estimation made in this study was based on district-wise census data on Hindus populations above 15 years (minimum age for the specific rituals of the cremation), death rates, and assuming that approximately 600 kg of fuelwood is necessary for the complete cremation. Based on these assumptions, the total annual use of fuelwood for cremations is estimated at **53,000 ad tons**.

Construction material

The construction material for rural houses, fences, stables, poles, etc. represent a sector of demand for woody biomass that is not accounted for in industrial wood demand statistics. The demand for construction material is mainly rural and is close to fuelwood demand, in terms of proveniences and production/marketing chains. For this, in order to account at least indicatively for this sector of woody biomass consumption, the demand for construction material is added to the rural demand for woodfuels by assigning an estimated per capita consumption. The consumption of construction material for fences, stables, rural houses construction and maintenance ranges between 5 and 20 kg (oven dry) per capita and per year, according to few available references encountered during WISDOM analyses in Rwanda, Mozambique and Sudan. In this study, in the absence of specific data, a tentative mid-range per capita value of 12.2 kg (air dry) per year was adopted, and applied to rural population, while 1/3 of such rate (4.1 kg) was applied to urban population. The total amount of woody biomass used as constriction material is estimated at **285,000 ad tons**.

Other sectors of consumption

For the estimation of the consumption of fuelwood in commercial and industrial sectors reference is made to the amounts estimated by WECS 2011, by development regions and by Eco Belts (Terai, Hills and Mountains). The total consumption in the **industrial sector** is estimated at **423,000 ad tons**, while that of the **commercial sector** is estimated at **428,000 ad tons**. Assuming that these consumptions are concentrated primarily in major agglomerations, they were tentatively located in municipalities and urban settlements.

2.2.2 Mapping fuelwood consumption

Once the sectors of consumption are defined and quantified, the subsequent step is to distribute such consumption over the territory with the best possible approximation.

From a spatial distribution perspective, two major types of consumption patterns may be distinguished: diffuse patterns, typical of the residential consumption, and other more localized sites, typical of industrial and commercial consumption sites, or even specific locations, such as biomass power plants and large tea factories. The first type is directly related to the distribution of the rural and urban population while for the second type the consumption is associated to special areas (i.e. urban areas only) or to specific locations such as towns or sub-urban areas or through geographic coordinates of known locations. Between these two extremes there are some types of consumptions, such as small industries, commercial and public users that are not ubiquitous but whose exact locations are not known. In these cases the distribution may be based on spatial proxies (elements of known spatial distribution) that are directly or indirectly correlated to the type of consumption considered.

In case of Nepal, the household sector dominates woodfuel consumption, and mapping human population is the prerequisite to mapping the relative consumption. But other consumption sectors, such as commercial (tea sellers, bakeries, restaurants, etc.) and industrial (brick making, blacksmithing etc.), are also more or less strongly related to population concentrations. For this, in absence of more precise data on the distribution of commercial and industrial users, urban population mapping was used as spatial proxy for the mapping of the consumption in these sectors.

Urban and rural population mapping.

Statistical and cartographic information relative to the distribution of the population at the level of Administrative Unit from Census 2011 obtained from the Central Bureau of Statistics (CBS). Figure 3 shows the main cartographic layers used to map the distribution of the population.

Location of Rural population:

The mapping of rural population (as defined by 2011 census) was done respecting the values reported at admin unit level (VDC). Within such units, the spatial distribution of the population was based on additional cartographic elements or spatial proxies such as built up areas and point settlement data. Roads and main trails were also used to locate probable sparse roadside settlements. Within a given unit, these features were used as spatial proxies of population presence to distribute census population where it's more probable to be found.

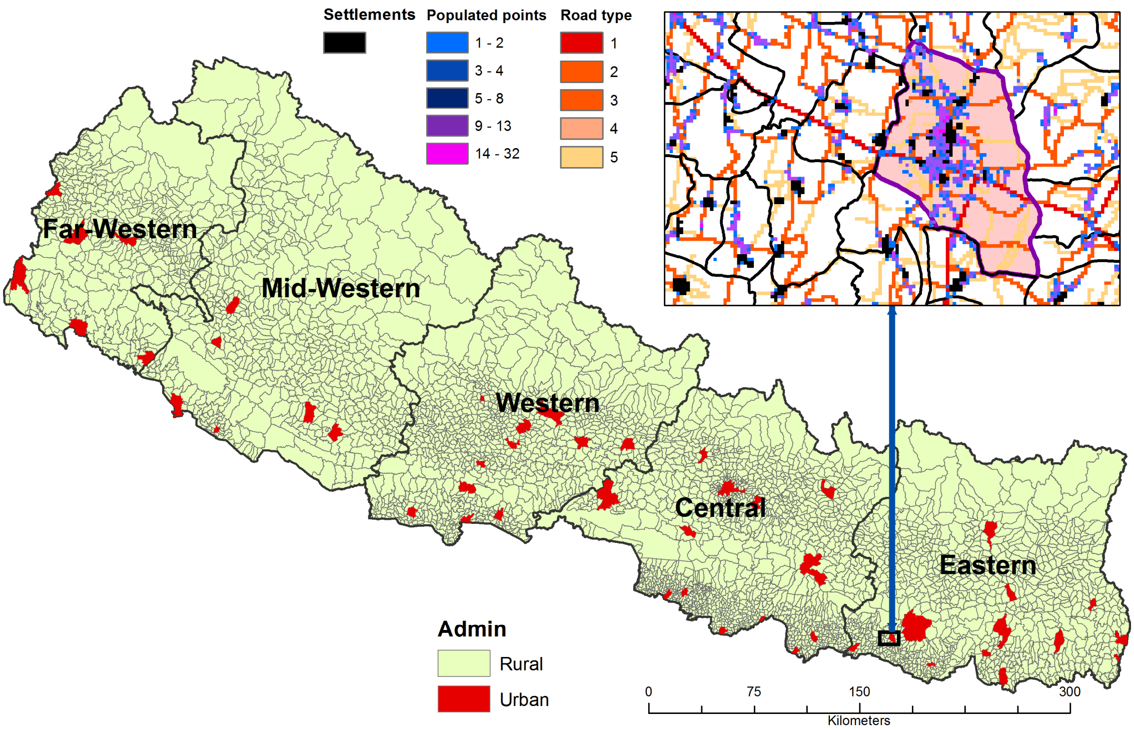
Location of Urban population:

The mapping of urban population (as defined by 2011 census) was done respecting the definitions (i.e. Municipalities) and values reported by the census. Within urban admin units, the spatial distribution of the population was based on cartographic elements or spatial proxies, such as urban boundaries.

Figure 10 in Results Section shows the resulting human population distribution map.

FIGURE 3

VDC and Municipalities of Census 2011 and spatial features used as proxies for distribution of rural and urban population within VDCs and Municipalities



2.2.3 Rural fuelwood users' adaptability

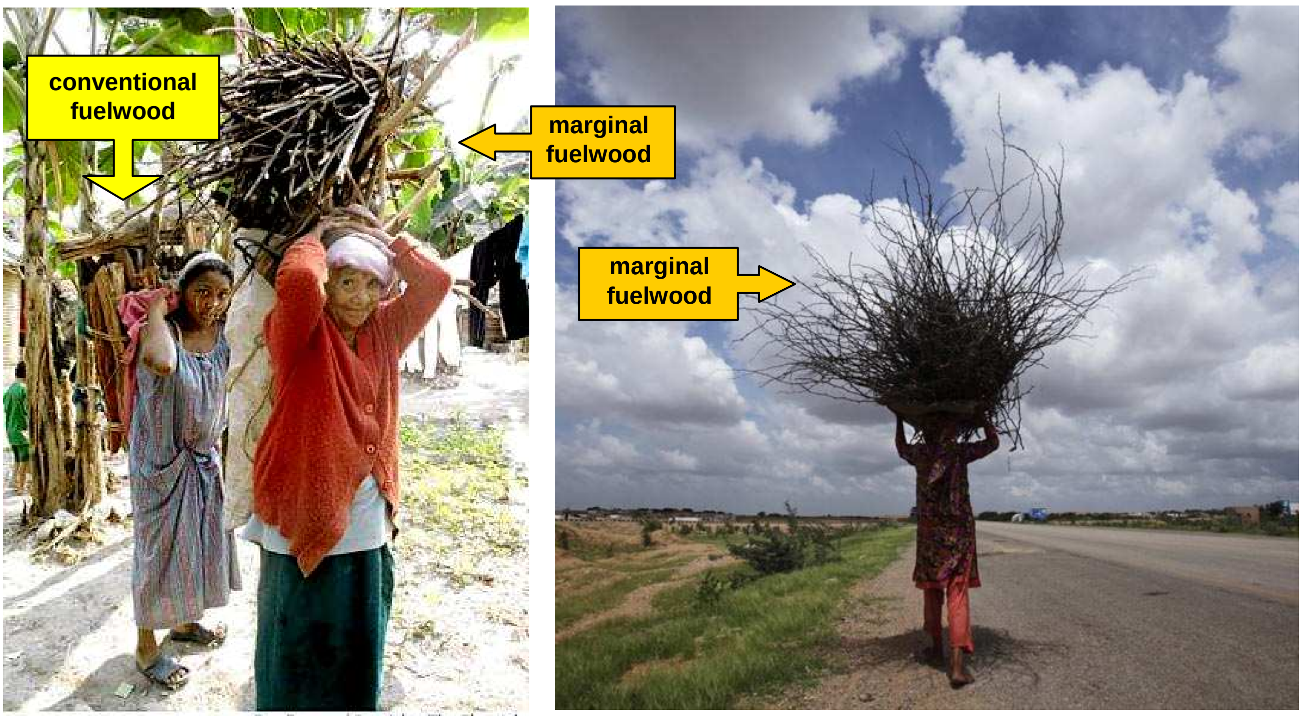
Fuelwood itself can be made of stem wood or branch wood, which are the more "conventional" fuelwood assortments, or made of twigs, smaller branches and shrub wood (Figure 4), which are wood assortments usually excluded from forest inventories and thus not accounted for among the conventional supply sources.

The fuelwood consumption by rural households is based on available survey data that do not distinguish between conventional and marginal fuelwood and it would be misleading to consider that the entire consumption is made of conventional fuelwood. The latter may be true for the regions sufficiently rich of wood resources but it may overestimate the real wood consumption in wood-poor areas, where conventional fuelwood is replaced by marginal fuelwood. In rural areas where wood resources are particularly scarce, like in the Terai, the most likely effect of shortage of "conventional" fuelwood is that rural households use of a higher proportion of twigs and small branches from annual pruning in the mix of fuels used to satisfy basic households needs. Twigs and small branches that are harvested annually are woody and thus they are usually classified as "fuelwood" in consumption surveys but they are not accounted for by conventional forest inventories and are not considered in the estimation of the productivity of natural forests, shrublands and plantations (based on MAI) that includes stem and branch wood available at end rotation (and thinning cycles, if applied). Hence, when doing supply/demand balance analysis, the consumption of such marginal wood products should not be deducted from the conventional fuelwood productivity.

Unfortunately there is no data on the quantity of marginal wood products used as fuel in rural households. In order to quantify, at least tentatively, the impact of wood scarcity on consumption regimes, the rural consumption of fuelwood was reviewed assuming that up to 50% of the fuelwood gap (i.e. the difference between the demand and the supply locally available) may be satisfied by "marginal" fuelwood, rather than by ordinary fuelwood from the felling of trees and shrubs. This was based on a preliminary supply/demand balance comparing the supply potential of conventional fuelwood and the entire fuelwood consumption on a local context of 6km, which allowed to calculate what percent of the demand may be fulfilled by local resources.

FIGURE 4

Conventional fuelwood and marginal fuelwood composed by twigs and small branches.



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The 50% limit in the substitution of conventional fuelwood by marginal wood products was arbitrarily selected and is only tentative. Other thresholds could be applied but the best approach would be to survey the situation in the field. The reduction of the demand for conventional fuelwood was applied only on rural areas, which depend primarily on local and mostly informal supply, and is concentrated only in Terai. The urban demand for conventional fuelwood was not modified since the supply in this case is formal and market-based.

The exclusion of marginal non-commercial wood products from the supply/demand balance of conventional woody biomass is probably more realistic but the fraction of these products in the rural fuel consumption is here only tentatively estimated This particular component of rural households' consumption should be studied in greater detail as it plays an important role in the overall supply/demand balance as well as in the soil nutrients cycles.

The impact of the use of these marginal wood products and farm residues is more consistent on the soil fertility than on the forest resources and woody biomass stock as it is normally intended. The impact is on the reduced re-integration of twigs, leaves and residues' nutrients into the soil of forests, plantations and agricultural fields. This is likely to produce a progressive loss of soil fertility, with consequent reduction of crop productivity and an increased level of vulnerability and worsened living conditions. The nexus between rural subsistence energy and soil fertility in Nepal certainly deserves a dedicated analysis.

2.3 SUPPLY MODULE

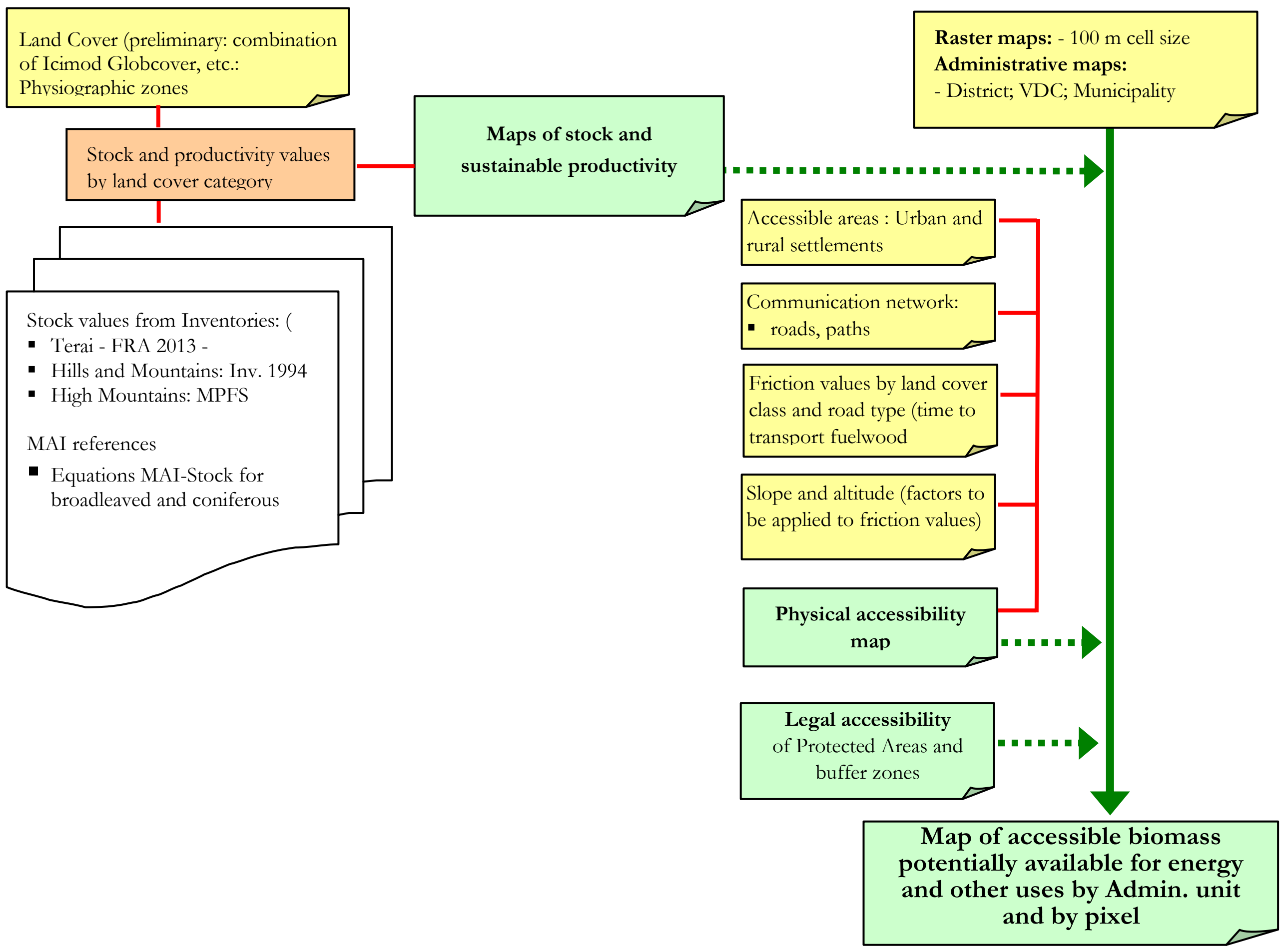
Scope of the WISDOM Supply Module is to produce a spatial representation of natural and man-made sources of woody biomass, their stocking and production potential. The Supply Module analysis includes woody biomass entirely, comprising the components that may serve as fuelwood as well as other non-energy uses such as industrial roundwood and construction material.

The estimation and mapping of the fuelwood supply potential is based on land cover information, describing the vegetation types and their location, and on field observations quantifying the stock and productivity of woody biomass, such as forest inventory data.

The flowchart in Figure 5 shows the source data and the main analytical steps of the Supply Module.

FIGURE 5

Flowchart of the main analytical elements of the Supply Module. Input data: cartographic (yellow); statistical (white); estimated variables (orange); thematic map outputs (green).



2.3.1 Cartographic layers

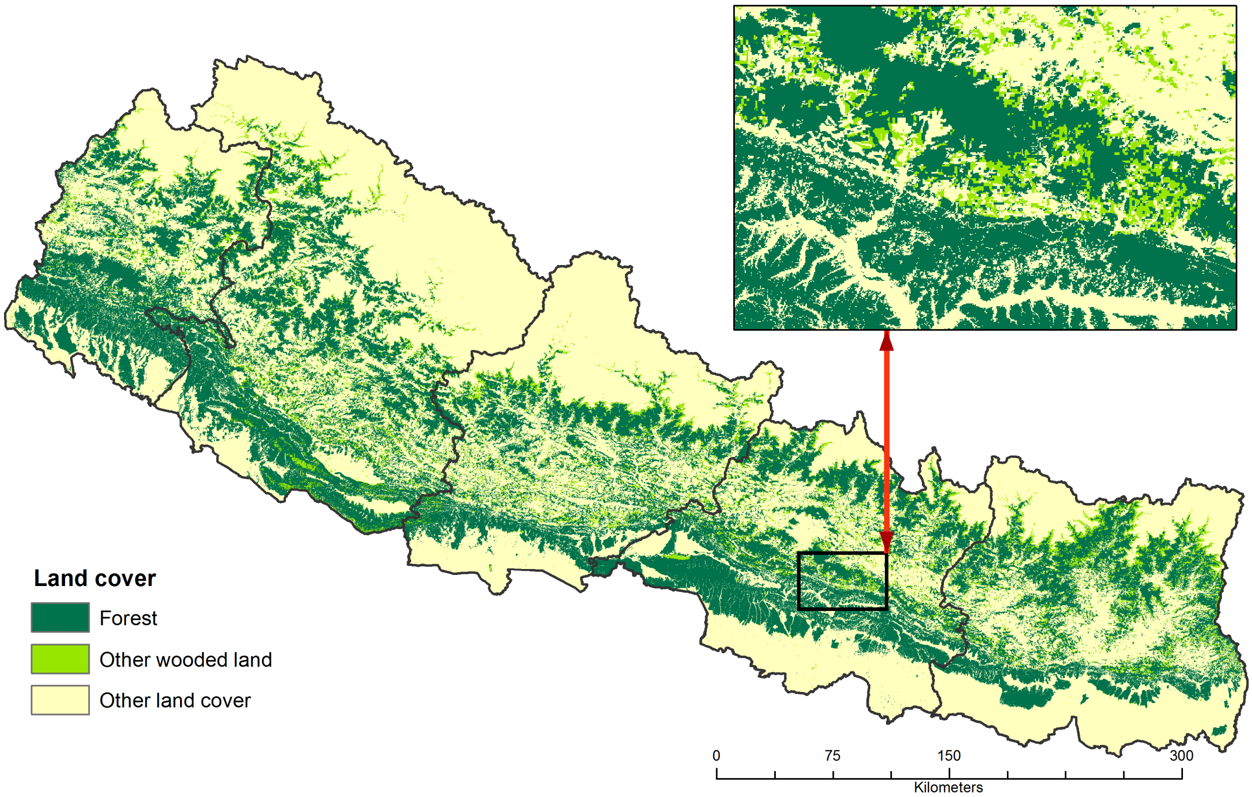
Given the straightforward relation between woody biomass sources and land use/land cover classes, the mapping of the potential sustainable supply is done on the basis of the land use/land cover map available and at the defined level of spatial detail.

In the absence of a recent reliable map of land cover, the available land cover and land use data was combined to form a preliminary land cover reference layer to be used as basemap of the Supply Module. The main land cover maps included are Icimod 2010 and FAO/ESA Globcover 2009. Figure 6 shows the raster version of the reference land cover map (displaying NEW_LCOVER attribute; see Annex 2 for more details). It is strongly recommended to replace this preliminary land cover dataset with reliable and up-to-date land cover map as soon as possible. Nonetheless, this preliminary dataset is considered adequate for the development of the Supply Module.

Reference map: **Biomass_base** in GDB **lc_biom_01.mdb**

FIGURE 6

Map of land cover used as reference map, produced combining Icimod 2010 and FAO/ESA Globcover 2009. Class displayed: NEW_LCOVER.



2.3.2 Stock and productivity

Woody biomass stock

Data of woody biomass stock from several forest inventories were used to estimate woody biomass stock by land cover classes and by physiographic zones. These included the preliminary results of the forest inventory of Terai (FRA), the inventory of 1994 for the Hills and Middle Mountains and the MPFS for the High Mountains. Stock values by combinations of Biomass_base classes NEW_LANDCOVER and GRIDCODE (i.e. Icimod classes) was based on field inventory plot data for Siwaliks, Hills and Mountain zones (1994 inventory) and for Terai (2012 FRA inventory). Stock values for High Mountain regions taken from 1989 Master Plan tables.

Assigning stock values to non-forest classes was particularly difficult due to limited and conflicting references:

- Pan-tropical WISDOM (GACC study) based on several references (Baccini, WHRC; Bangladesh inventory by FAO; etc..) assigns **41 od t/ha** to cropland. This value seemed to be too high for Nepal since farmland in Bangladesh and in parts of India are richer of "homestead forests" than Nepal.
- A very limited number of field plots carried out in agricultural areas by FRA Project in Terai indicate a biomass stock ranging between 10 ad m^3/ha (cropland with sparse trees) and 4 ad t/ha (cropland). These values probably refer to stem volume, excluding small branches. In addition, it is not clear whether the survey area included village areas, where most trees and other woody vegetation are concentrated.

In the absence of a reliable reference we assumed that the aboveground biomass of agricultural areas be 10 ad t/ha.

The dendroenergy biomass (DEB) is the fraction of the aboveground biomass (AGB) that is suitable as fuelwood. DEB includes the total aboveground woody biomass, less stump and twigs. With reference to the total AGB, it is calculated as follows:

de_biom_t_ha (DEB) = [AGB_t_ha]*(1-0.15-0.039) [15% leaves and twigs; 3.9% stump]

Productivity

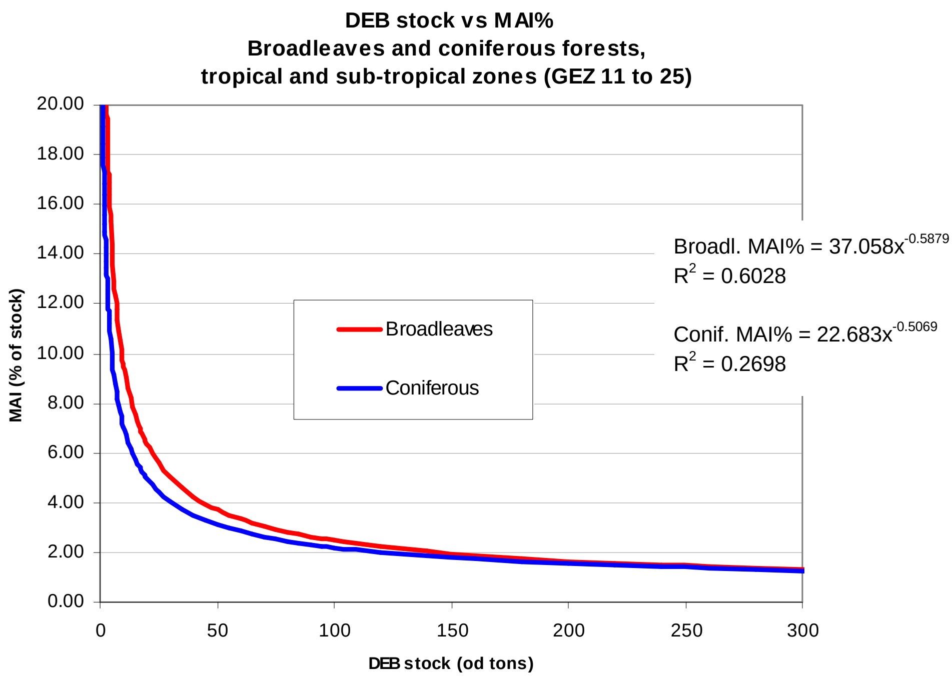
As usual, the sustainable productivity of natural formations is a far less known parameter than the stock due to the scarcity of permanent sample plots, which are the only reliable sources of data for the estimation of the Mean Annual Increment (MAI). In order to fill this critical data gap, the MAI was estimated by applying simple equations relating stock and MAI values as percent of stock for coniferous and broadleaved formations from a set of international field observations relative to similar ecological contexts as Nepal, as shown in Figure 7.

MAI_DEB_percent (Coniferous forest formations)= ([de_biom_t_ha]^-0.5069)*22.683 [based on tropical and sub-tropical stock-MAI values for broadleaved formations]

MAI_DEB_percent (All other formations)= ([de_biom_t_ha]^-0.5879)*37.058 [based on tropical and sub-tropical stock-MAI values for broadleaved formations]

FIGURE 7

Stock vs MAI relations for natural broadleaves and coniferous formations used to estimate the MAI



2.3.3 Accessibility

In this assessment the accessibility has two components. One component is legal accessibility, which is based on the legal rights of wood harvesters to extract wood from a particular area. The second component is physical accessibility, which is based on the ability of wood harvesters to reach a given location. This may be determined by the distance between human settlements and woodfuel resources, but is mediated by infrastructure characteristics such as the existence of footpaths, roads, as well as factors like topographical gradients and other obstacles. We explore details of each component below.

2.3.3.1 Legal accessibility

The legal accessibility to woody biomass resources is determined on the basis of protection status and categories. Legal restrictions may range from total access interdiction to harvesting limitations of varying degrees. In most cases fuelwood harvesting if permitted to local communities for their own use while commercial fuelwood and charcoal production are forbidden. In case of Nepal, several categories of Protected Areas, covering a total area of 3,439,988 hectares, with a varying range of access rights to local communities for fuelwood harvesting, while commercial fuelwood production is thoroughly forbidden. The right of access is not precisely defined but discussion with qualified informants allowed to define a percent access value for each protection category, as discussed in detailed in Annex 4.

2.3.3.2 Physical accessibility

The estimation of the physical accessibility of biomass resources is based on a **fuelwood transport time map** covering Nepal following and adapting the procedure described by Nelson (2008) for the global Travel Time map to the nearest city of 50,000, or more people in year 2000 and by Drigo (2013, GACC Project, in progress). The main differences with previous studies include a redefinition of target locations and friction data based on detailed national data (DTM 30m, land cover and road, trail, paths network data) and the adaptation of friction factors to estimate the transport of fuelwood including going and returning with fuelwood load.

This map is the result of an accessibility model that considers target locations (in this case accessible features and populated places) and cost, or friction surface, based on several national datasets that represent roads, terrain features (slope, altitude) and land cover.

The subsequent fundamental step for the scope of this study is to convert transport time values (minutes to/from the nearest accessible feature) into accessibility factor to be applied to DEB supply sources. This is done under the assumption that the higher the transport time to the nearest populated place or communication infrastructure, the lower the percentage of accessible resources.

In the absence of specific reference data, it was here assumed that wood resources (for energy use) that are more than 10 hours of transport time from the nearest accessible feature (10 hrs collection time as per CBS-NLSS2010) may be considered as totally inaccessible and that the accessible fraction of DEB resources decreases progressively with the increase of travel time.

In this study the physical accessibility is used in two separate phases of analysis:

1. In the Supply Module, the off-road accessibility of woody biomass resources is used to estimate the fraction of the total MAI that is accessible to rural users and to commercial woodfuel producers.
2. In the woodshed analysis, accessibility is based on each Nepal's major consumption sites such as urban centers and densely populated rural areas. In addition to the off-road accessibility, this analysis also includes distances along roads and rivers to reach the selected consumption sites.

Details of the travel time map development process, data sources and results are provided in Annex 5.

2.3.4 Accessible and available MAI

2.3.4.1 Physical and legally accessible MAI

The estimation and mapping of accessible productivity is done by applying the legal and physical access limitations, in form of percent accessible maps, to the map of DEB MAI.

2.3.4.2 Available MAI

Not all accessible MAI can be assumed available for fuelwood production or as construction material. The main competing use is the industrial roundwood that feeds wood processing industries such as furniture making, panels, etc.

However, the reference values for the annual production of industrial roundwood production varies considerably:

FAO FRA Country Report for year 2003-2007:	152,000 m^3
FAOstat (same value for 1998 to 2012)	1,260,000 m^3
Nepal Forestry statistics of District-wise timber sale (year2010-11)	**161,173 m^3**

FAOstat value seems very high and it's not clear how it's estimated. On the other hand the official record of timber sale appears rather low for Nepal and it's likely that the record capture only part of the actual production. The Nepal Forestry reference was used as main reference but to this value a tentative 20% was added on account of illegal and unrecorded production. The amounts reported by Forest Department statistics on timber sale by district, increased of 20 % were deducted from the accessible resources in the respective districts. The district-wise statistics of industrial roundwood production and the values actually deducted are presented in Annex 3.

In the absence of data on the location of industrial roundwood production sites, the deduction was spatially distributed on accessible forest resources.

2.4 INTEGRATION MODULE

The scope of the Integration Module is to combine the parameters developed in the demand and supply modules by discrete land units (pixels-level and sub-national unit-level) in order to discriminate areas of potential deficit and surplus according to estimated consumption levels and sustainable production potentials.

The first and most important result of the integration module is the balance between the accessible and available potential productivity and the total consumption of woody biomass for energy generation and other uses.

In order to describe the various planning dimensions of wood energy, the supply/demand balance analysis will be carried out at the following three levels:

(i) Cell-level balance, which is the basis of all other balance analyses,

(ii) balance in a local context, few km around consumption sites, representing the informal self-supply horizon of rural and peri-urban households and,

(iii) balance based on the “commercial” fraction of the local surplus (resulting from the previous level) considered as source of commercial woodfuel production systems serving distant consumption sites.

2.4.1 Pixel-level balance

The supply/demand balance at the level of individual map pixel (or cell) is calculated by deducting the pixel-level consumption from the pixel-level available productivity. The calculation of the supply/demand balance by individual 1-hectare cell has an useful accounting function but it represents a somewhat virtual balance since individual pixels are usually either a production or a consumption site. An example of pixel-level balance is shown in Figure 8. (left-side map).

2.4.2 Local neighborhood balance

In order to achieve a realistic perception of the supply/demand balance it is necessary to combine the consumption and the supply potential within an area related to the real supply zone. In the case of rural and peri-urban households, the distance that household’s members are prepared to go to fetch fuelwood, on foot or by local transport means are good parameters to estimate the actual supply area. This should be estimated in terms of time needed to reach the resources and to transport them to the village but the underlying spatial modeling would be too complex and the harvesting horizon is here simplified to a radius of 3 km around each pixel.

An example of the balance analysis in a local context is shown in Figure 8 (middle map). Comparing the local balance to the pixel-level balance it is interesting to see how the local context tends to render more visible the deficit areas, giving a more realistic perception of deficit and surplus zones

2.4.3 “Commercial” balance and "commercial" surplus

The analysis of the “commercial” balance is based on the consideration that the management and commercial exploitation of sparse resources may be uneconomical. In a local supply/demand context dominated by direct fuelwood collection all wood resources may be considered suitable for local (rural) consumers, but when the demand and supply areas are far apart and the supply system is market driven, then only the wood resources that are economically viable to exploit are likely to be utilized.

For woodfuels markets such as those of urban centers, the supply potential consists of the "commercial" fraction of surplus resources resulting from local balance. The "commercial" surplus is estimated by first accounting for the supply that is utilized for local demand, which includes all available DEB production potential, and second, estimating the quantity of remaining DEB that is suitable for commercial utilization, which is limited to the legally accessible resources that justify transport and management costs. To assess the commercial surplus some basic quantitative thresholds related to stock and productivity were defined as follows:

- One threshold concerned the minimum stocking required for profitable fuelwood production, which is here preliminarily set to 14.6 tons / ha, air dry[2].
- The second threshold concerned the rotation period determined by the estimated annual surplus of the local supply/demand balance: only the areas with surplus levels that guarantee rotation periods lower than 30 years were considered eligible. To reach such condition the available surplus MAI must exceed 0.5 ad t/ha/year.

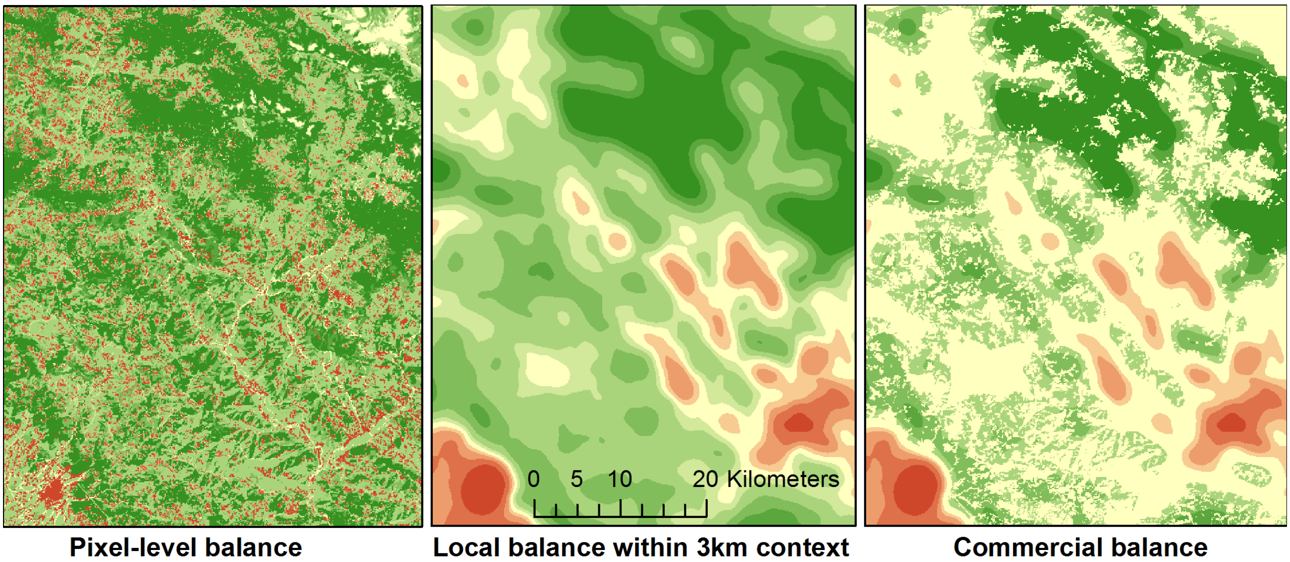
Consequently, only the accessible areas with a stock above 14.6 ad t/ha and a surplus above 0.5 odt/ha/year were considered as potential commercial sources. In addition, ALL Protected areas are excluded from commercial exploitation, including Buffer Zones in which local communities are entitled to exploitation of own use. An example of commercial balance analysis is shown in Figure 8 (right hand map).

At the local level of analysis it is important to verify the economic viability of the various situations with local operators and managers and to define the "economically viable" minimum surplus values that apply locally. .

The commercial balance analysis remains theoretical since it implies that the economically viable resources are rationally managed, such that the potentially sustainable increment is exploited entirely, without depleting the forest capital. The commercial balance is therefore useful for defining the theoretical limits of sustainable forest management but is unlikely to represent existing processes. Current exploitation is often unregulated, leading to overexploitation in some areas and under-exploitation in others.

FIGURE 8

Example of balance calculated at pixel-level, on a 3-km local context and commercial balance excluding non-commercial surplus resources. Example located over Rolpa, Pyuthan and Rolpa Districts, MWDR.



[2] There is no reference to the minimum stock for profitable fuelwood production in Nepal. The value here proposed was derived from a study on charcoal production in Mozambique (Mancini et al, 2007). In this study, the DEB stock threshold was set at 15 t / ha air-dry considering that below such level the cost of kiln preparation would be unprofitable.

2.5 WOODSHED ANALYSIS

2.5.1 Mapping commercial demand pressure

Once the development of the WISDOM Base is complete for the whole area and the commercial balance maps are available, it is possible to outline the potential sustainable supply zones of specific major consumption sites, keeping into account the consumption of surrounding urban and rural areas as well as the resources realistically available. These zones are termed “woodsheds” in analogy with the familiar geographical concept of watersheds (Drigo e Salbitano, 2008).

The woodshed of a given consumption site may be defined as the minimum area around the site in which the cumulative woodfuels balance between the deficit areas and the (commercial) surplus areas is non-negative.

When a single consumption site is considered, the woodshed is determined by the physical accessibility of the available surplus resources. However, when several consumption sites are considered at the same time, the woodshed is determined by the combined effect of both physical accessibility of available resources and of woodfuel demand exerted by each site considered.

In order to combine efficiently these two components, the analysis will be carried out through weighted interpolation using Dinamica EGO processing environment. The model applied considers:

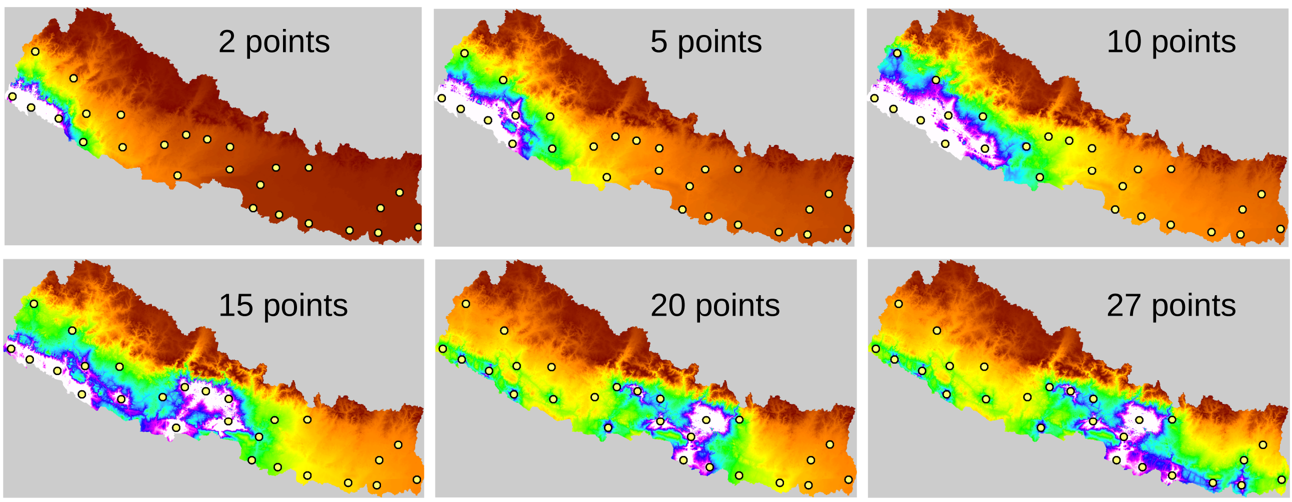
- <u>as staring points of analysis,</u> the location of deficit peaks (Categorical Map) with the associated local deficit values
- <u>as weighting factor of interpolation,</u> the friction map created for the analysis of accessibility, reporting the travel time needed to cross the cells, in minutes per meter.

The model creates an interpolation map for each individual point using the friction map as weighting factor. These maps are then added together to form the cumulative "pressure" map determined by the intensity and location of the major deficit areas. Examples of the progressive interpolation are shown in Figure 9, while the final result is shown in Figure 20 in Results Section.

By means of this combined cost factor, the cities with higher demand “produce” wider woodshed buffers while the cities with lower demand “produce” narrower buffers, well representing the territory under urban influence/pressure.

FIGURE 9

Examples of the progressive analysis combining demand pressure and physical accessibility for 27 major deficit sites.



Once the country-cumulative weighted interpolation map is produced, the procedure for the delineation of the woodshed of the selected deficit sites is to calculate the supply/demand balance of each buffer (applying zonal statistics to the commercial balance) and to progressively expand the area buffer by buffer until the cumulative value of the commercial balance reaches a positive value, indicating that within such territory the supply potential (i.e. the commercial surplus) matches the demand.

To be noted, however, that the woodshed analysis tells what should be the harvesting area in order to guarantee the sustainable supply of the needed woody biomass, assuming the rational and sustainable resources management system. The woodshed analysis doesn't tell what the actual harvesting area is, but it provides a revealing vision of the territory under urban influence and a clear target for forest management.

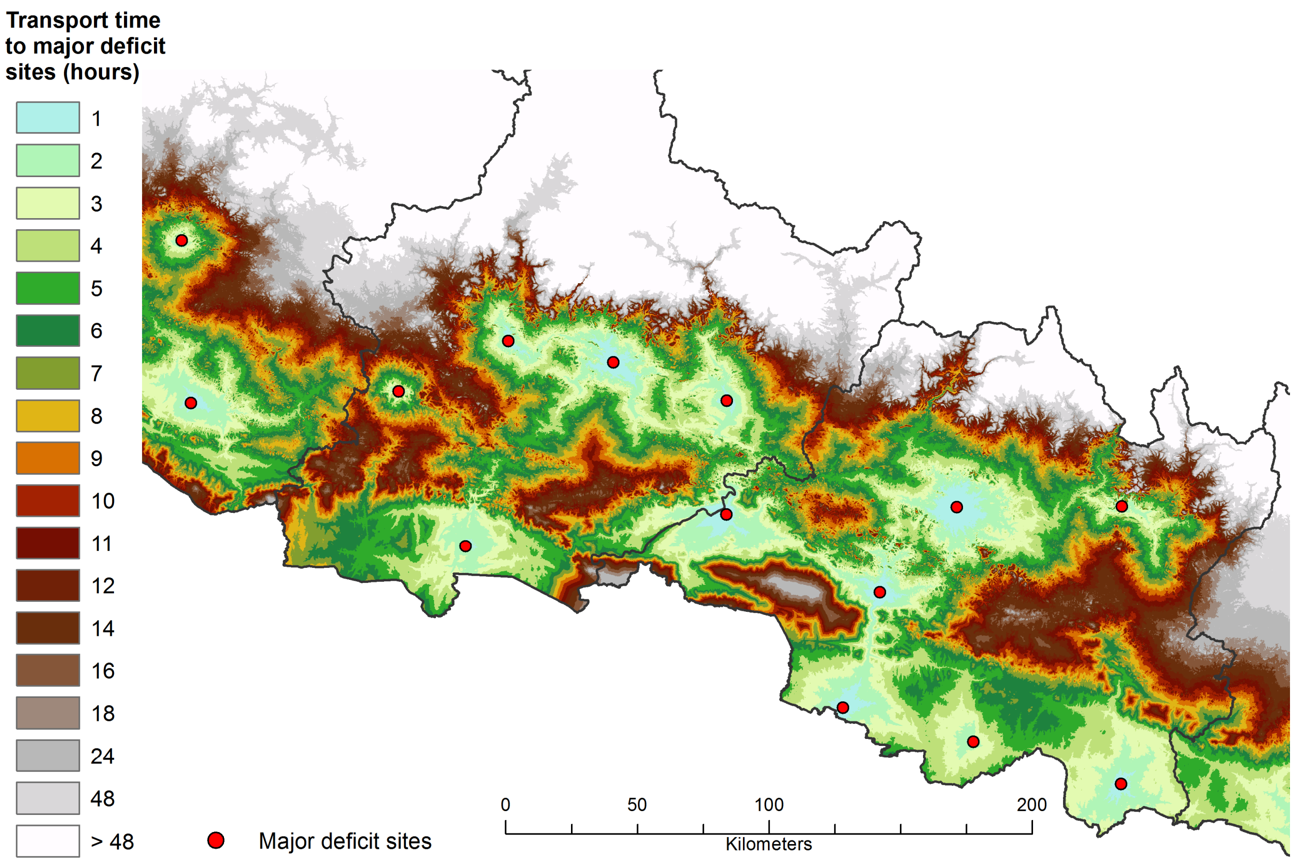
2.5.2 Transport time threshold

The woodshed zone is determined by the availability of local surplus resources and commercial demand, which may include resources that are at great distance from market areas. In these cases the transport cost may become too high and the actual harvesting areas are likely to be concentrated on wood resources that are closer to market areas. By conducting cost-distance analysis on the same major deficit points used for woodshed analysis using transport time as cost factor (see Annex 5 for a description of physical accessibility model), we can segment the resources according to transport time and thus we can apply threshold values as limit of actual supply zones in consideration of transport costs. Figure 10 shows the results of the transport time analysis.

In this analysis we adopted a 12-hours travel time threshold (i.e. from market site to harvesting place and then loaded from harvesting place to roadside and to market), which implies approximately one full days of transport, This was preliminarily selected as the economic limit of the transport component. This threshold is not based on direct observations but only through "expert opinions" and needs to be verified in the field

FIGURE 10

Transport time to the major deficit sites. Example showing Central and Western Development Regions.



3
RESULTS

Demand Module results

The map of 2011 population distribution, essential ingredient in the development of the Demand Module, is shown in Figure 11. The map representing the total consumption of fuelwood[3] in all sectors is shown in Figure 12.

Table 1 provides the summary of fuelwood consumption by Development Region and Physiographic zones. In consideration of its relevance in the analysis of supply/demand balance, distinction is made, at least tentatively, between "conventional" fuelwood made of stemwood and branches and "marginal" fuelwood, made of twigs and annual pruning of farm trees and shrubs.

TABLE 1

Fuelwood consumption by Development Region and Physiographic zone. Distinction is made between conventional fuelwood and marginal fuelwood.

Development Region	Physiographic Zone	**Rural consumption (conventional + marginal)**	**Urban consumption (conventional)**	**Total consumption (conventional + marginal)**	**Total consumption (conventional only)**
		kt ad	kt ad	kt ad	**kt ad**
Far Western	HighMount	3	0	3	**3**
	MidMount	264	0	264	**264**
	Hills	539	39	578	**578**
	Siwaliks	53	1	54	**54**
	Terai	436	70	507	**447**
Mid Western	HighMount	13	0	13	**13**
	MidMount	455	0	455	**455**
	Hills	708	56	764	**764**
	Siwaliks	275	35	309	**301**
	Terai	345	41	386	**324**
Western	HighMount	14	0	14	**14**
	MidMount	167	0	167	**167**
	Hills	1,104	184	1,287	**1,287**
	Siwaliks	104	46	150	**150**
	Terai	339	57	397	**352**
Central	HighMount	2	0	2	**2**
	MidMount	168	2	170	**170**
	Hills	1,384	293	1,678	**1,678**
	Siwaliks	299	157	457	**443**
	Terai	1,043	211	1,254	**958**
Eastern	HighMount	5	0	5	**5**
	MidMount	178	0	178	**178**
	Hills	870	59	930	**930**
	Siwaliks	136	77	213	**213**
	Terai	657	184	841	**764**
Nepal		**9,562**	**1,513**	**11,075**	**10,513**

[3] The consumption in the residential sector is inclusive of construction material for fences, house repairs etc.

Supply Module results

Maps of DEB stock per hectare (and per pixel) is shown in Figure 13. Maps of per hectare values of total MAI, and physically & legally accessible MAI are shown in Figure 14 and Figure 15. Finally, Figure 16 shows the same map, but only with biomass that is potentially available for energy use after accounting for industrial uses of roundwood like timber and pulp production.

Table 2 provides the summary of the same items (plus total aboveground biomass estimates) by Development Region and Physiographic zones.

TABLE 2

Summary by Development Region and Physiographic zone of aboveground biomass (AGB), dendroenergy biomass (DEB), Mean Annual Increment (DEB MAI), legally and physically accessible DEB MAI and DEB MAI available for energy uses.

		AGB	DEB	DEB MAI	accessible DEB MAI	available DEB MAI
		kt ad	kt ad	kt ad		**kt ad**
Far Western	HighMount	2,306	1,891	122	8	**8**
	MidMount	77,234	62,728	1,021	538	**538**
	Hills	45,886	37,362	1,056	1,031	**1,031**
	Siwaliks	36,352	29,491	561	535	**532**
	Terai	31,801	25,886	553	482	**479**
Mid Western	HighMount	6,555	5,317	245	30	**30**
	MidMount	175,106	142,011	2,339	1,381	**1,381**
	Hills	44,695	36,247	1,170	1,164	**1,163**
	Siwaliks	76,176	61,911	1,266	954	**952**
	Terai	19,716	16,004	374	264	**261**
Western	HighMount	5,722	4,642	222	28	**28**
	MidMount	76,668	62,178	1,050	657	**655**
	Hills	53,091	43,057	1,367	1,351	**1,346**
	Siwaliks	34,362	27,879	560	518	**512**
	Terai	13,138	10,693	347	346	**342**
Central	HighMount	3,924	3,212	115	5	**5**
	MidMount	68,430	55,651	887	444	**440**
	Hills	62,184	50,432	1,438	1,396	**1,388**
	Siwaliks	96,279	78,168	1,506	1,042	**1,027**
	Terai	25,677	20,872	669	636	**620**
Eastern	HighMount	5,363	4,356	189	17	**16**
	MidMount	87,521	71,022	1,212	786	**781**
	Hills	46,366	37,615	1,330	1,321	**1,274**
	Siwaliks	35,586	28,860	592	580	**576**
	Terai	14,752	11,985	585	578	**569**
Nepal		**1,144,889**	**929,469**	**20,776**	**16,090**	**15,954**

Integration Module results

The map of pixel-level supply/demand balance is shown in Figure 17, while the map of the Local balance estimated within local harvesting context of 3 km is shown in Figure 18. The third balance map, shown in Figure 19, represent the "commercial" balance which shows the deficit areas entirely (red areas) but only the local surplus (green areas) considered suitable to commercial fuelwood production.

Table 3 presents the simple supply/demand balance by Development Region and Physiographic zones.

Woodshed analysis and expected forest degradation

The map in Figure 20 shows the expected harvesting pressure determined by the demand for fuelwood exerted by the major deficit sites of the Country (27 sites were identified) combined with the physical accessibility (intended as transport time). Figure 21 shows the areas where commercial harvesting is likely to concentrate, considering the sustainable woodshed (territory with commercial supply potential matching the demand) and transport threshold, here set at 12 hours. The map in Figure 22 shows the commercial balance of the woodshed area within 12 hours of transport time from the major deficit sites. The map in Figure 23 shows probable harvesting intensity determined by projecting the fuelwood deficit onto the commercial surplus areas according to harvesting pressure (of Fig. 20) and surplus level. The map in Figure 24 shows the sustainability of commercial fuelwood harvesting, while Figure 25 shows only the distribution of the un-sustainable harvesting, which represents a quantitative measure of the forest degradation induced by excessive fuelwood harvesting.

Table 3 presents the expected degradation induced by excessive fuelwood harvesting by Development Region and Physiographic zones. The total expected degradation of forests and other woody formations is estimated at 758,000 tons. It should be emphasized, however, that this was estimated assuming the "optimal" exploitation of resources, through homogeneous harvesting (i.e. not leaving some accessible resources untapped and others overexploited). This assumption may be realistic for the forests managed by local communities but might be too optimistic for other areas. Therefore, this should be considered as the MINIMUM level of degradation. Detailed knowledge on the areas under community management plans and un-managed public forests, when available, will allow a more accurate estimation and mapping of actual forest degradation.

TABLE 3

Summary by Development Region and Physiographic zone of supply/demand balance and of the expected degradation induced by excessive fuelwood harvesting.

		total consumption (conventional only)	available DEB MAI	simple balance	Expected degradation within woodshed
		kt ad	kt ad	kt ad	kt ad
Far Western	HighMount	3	8	**6**	
	MidMount	264	538	**274**	**-0.1**
	Hills	578	1,031	**453**	**0.0**
	Siwaliks	54	532	**479**	**-1.7**
	Terai	447	479	**32**	**-6.1**
Mid Western	HighMount	13	30	**17**	
	MidMount	455	1,381	**926**	**0.0**
	Hills	764	1,163	**399**	**0.0**
	Siwaliks	301	952	**650**	**-0.1**
	Terai	324	261	**-64**	**-1.1**
Western	HighMount	14	28	**14**	
	MidMount	167	655	**488**	**-2.1**
	Hills	1,287	1,346	**59**	**-43.4**
	Siwaliks	150	512	**362**	**-24.7**
	Terai	352	342	**-10**	**-1.8**
Central	HighMount	2	5	**3**	
	MidMount	170	440	**269**	**-14.6**
	Hills	1,678	1,388	**-289**	**-259.3**
	Siwaliks	443	1,027	**584**	**-215.1**
	Terai	958	620	**-338**	**-142.2**
Eastern	HighMount	5	16	**12**	
	MidMount	178	781	**603**	
	Hills	930	1,274	**344**	**-2.0**
	Siwaliks	213	576	**363**	**-25.3**
	Terai	764	569	**-195**	**-18.1**
Nepal		**10,513**	**15,954**	**5,442**	**-758**

FIGURE 11

Map of 2011 Population distribution

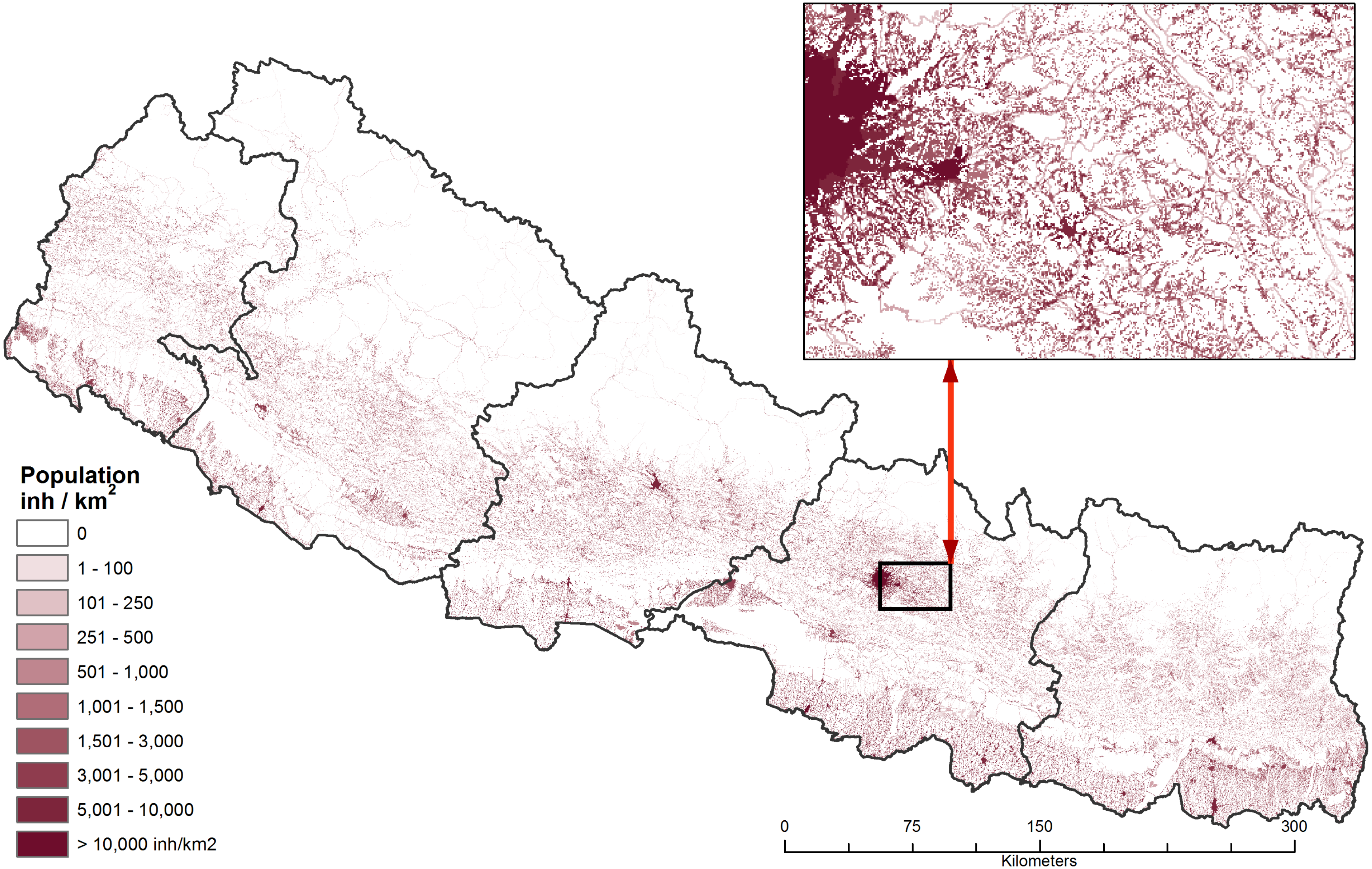


FIGURE 12

Map of "conventional" fuelwood consumption (all sectors).

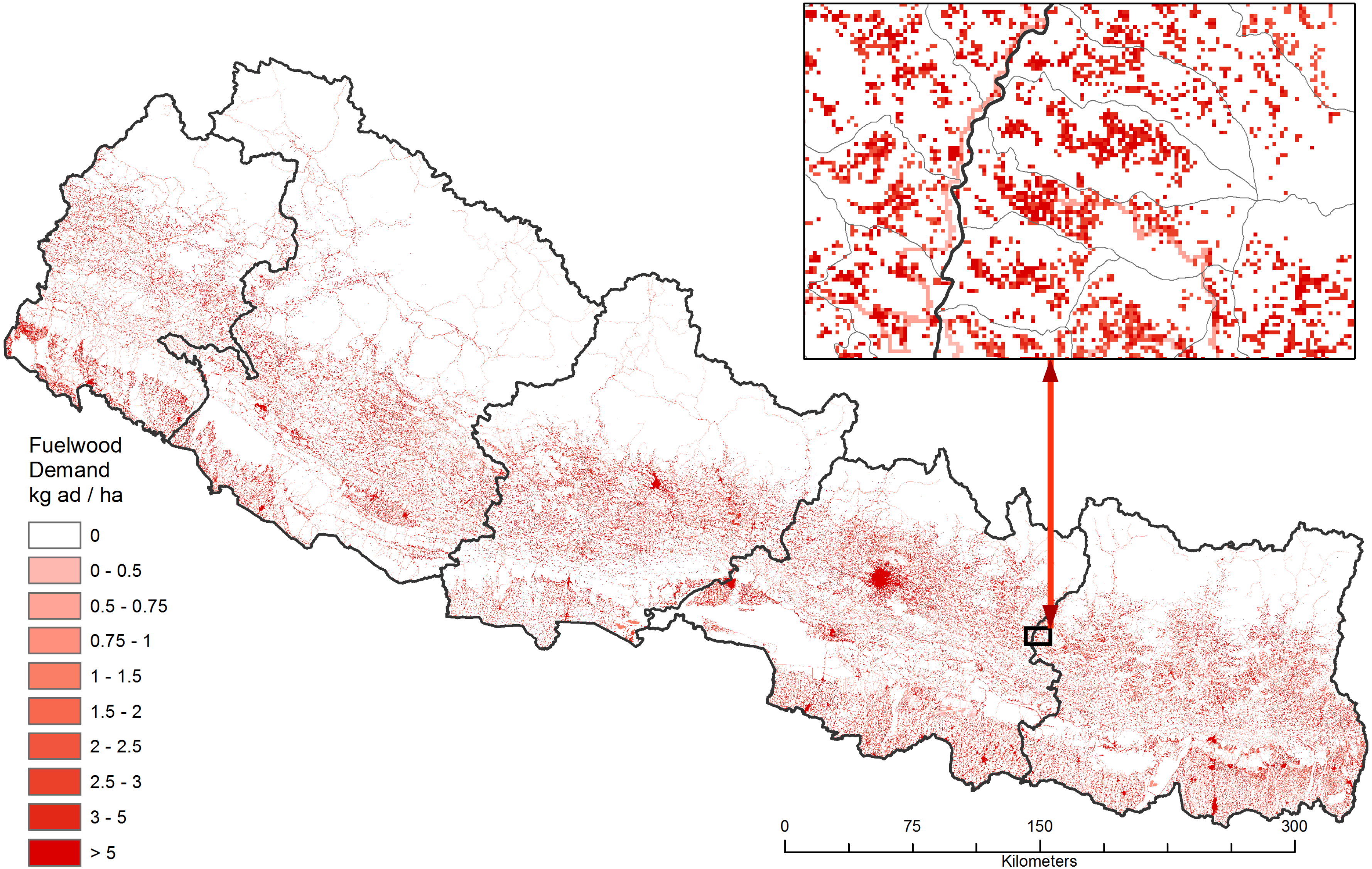


FIGURE 13

Map of dendroenergy biomass (DEB) distribution.

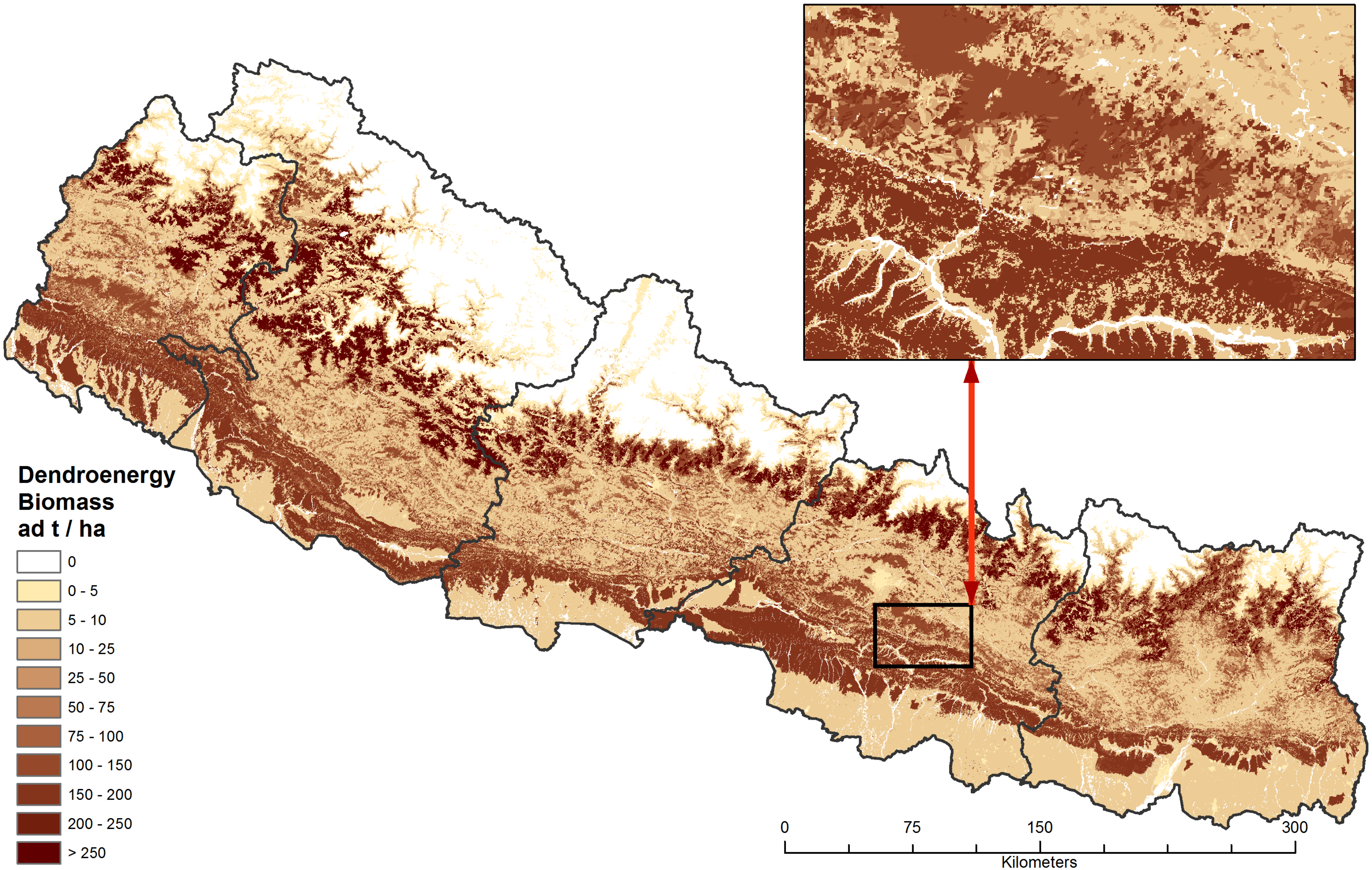


FIGURE 14

Map of total mean annual increment of dendroenergy biomass (DEB MAI)

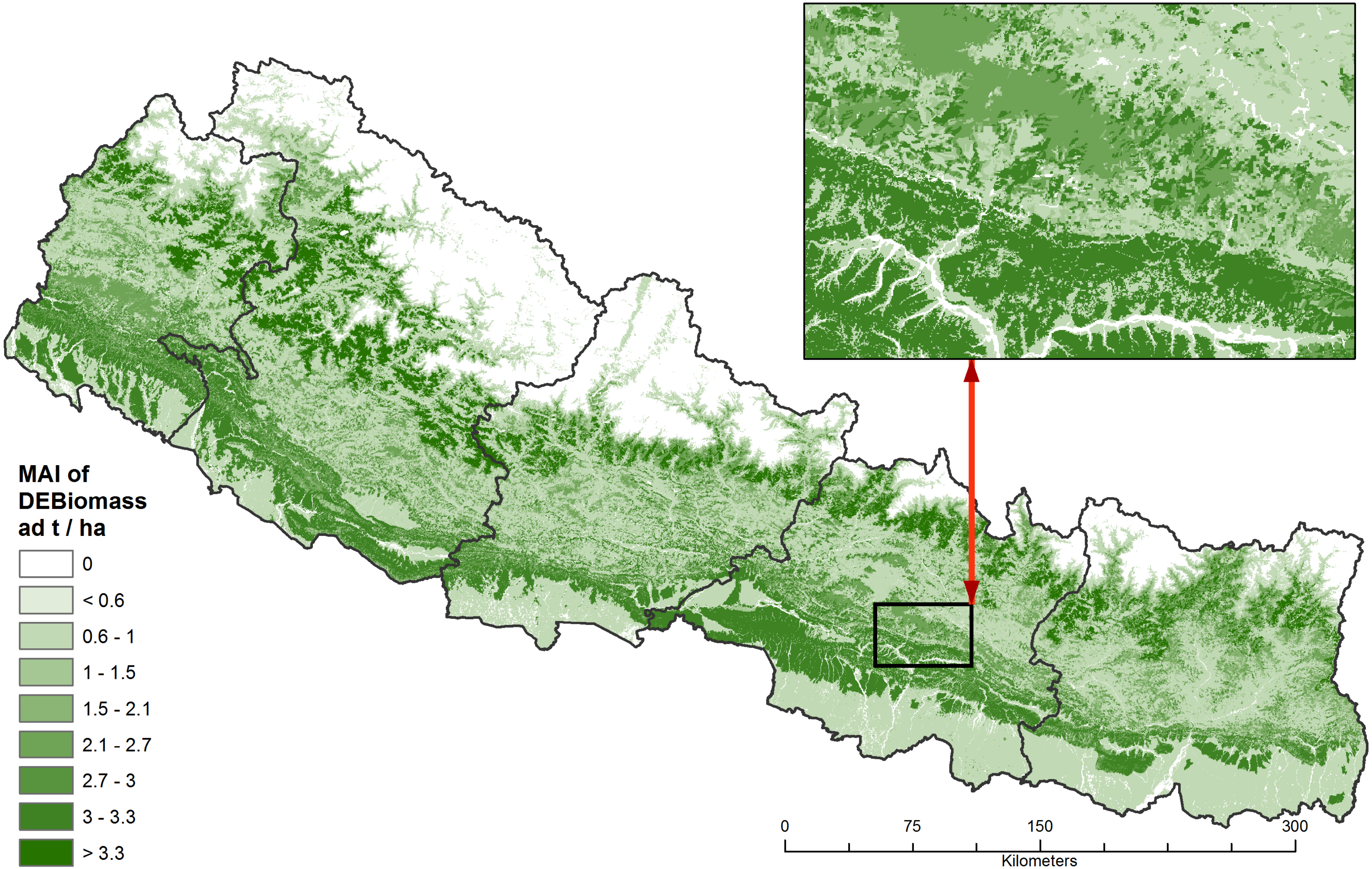


FIGURE 15

Map of physically and legally accessible DEB MAI.

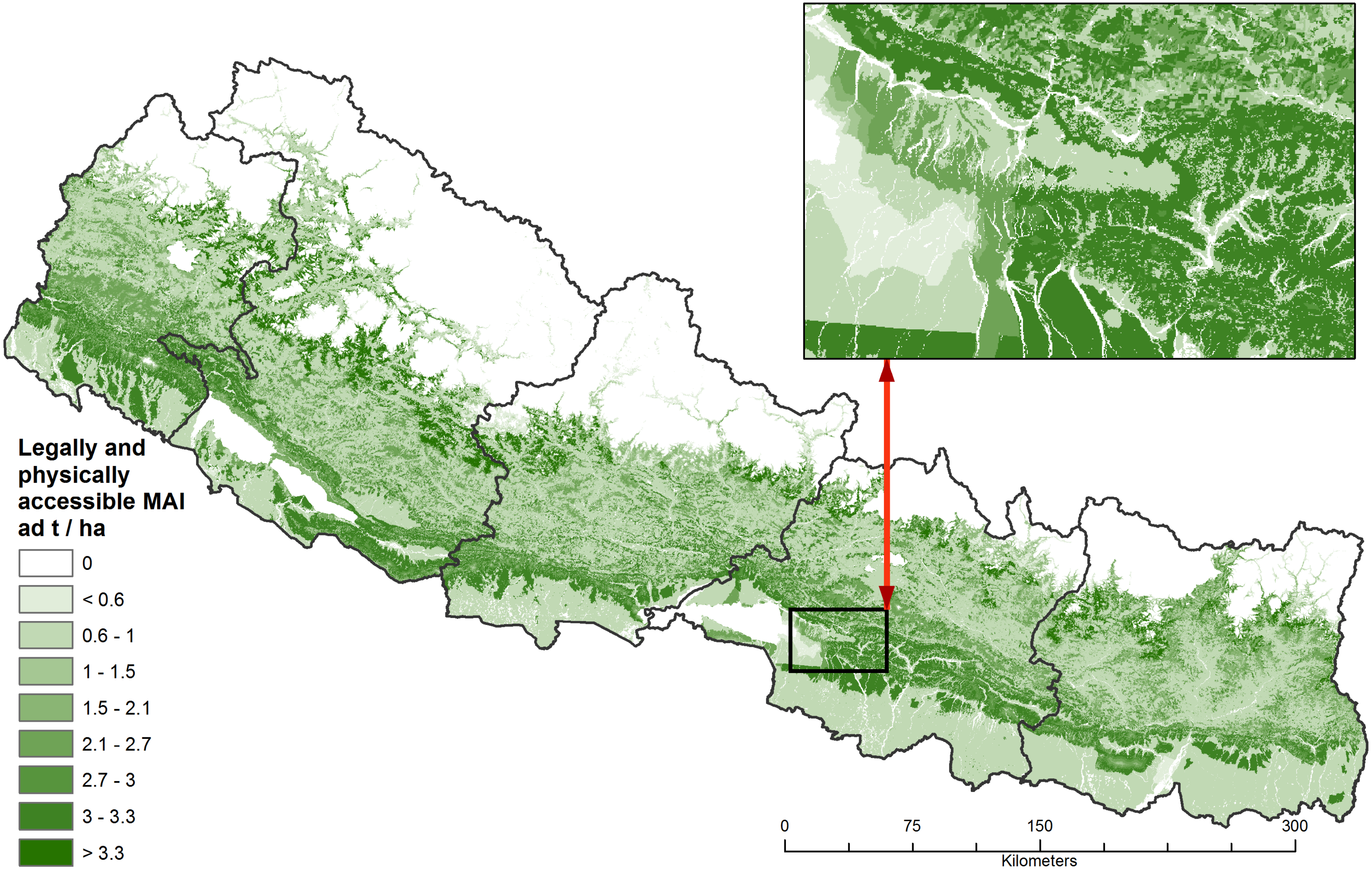


FIGURE 16

Map of the fraction of the physically and legally accessible DEB MAI that is potentially available for energy use.

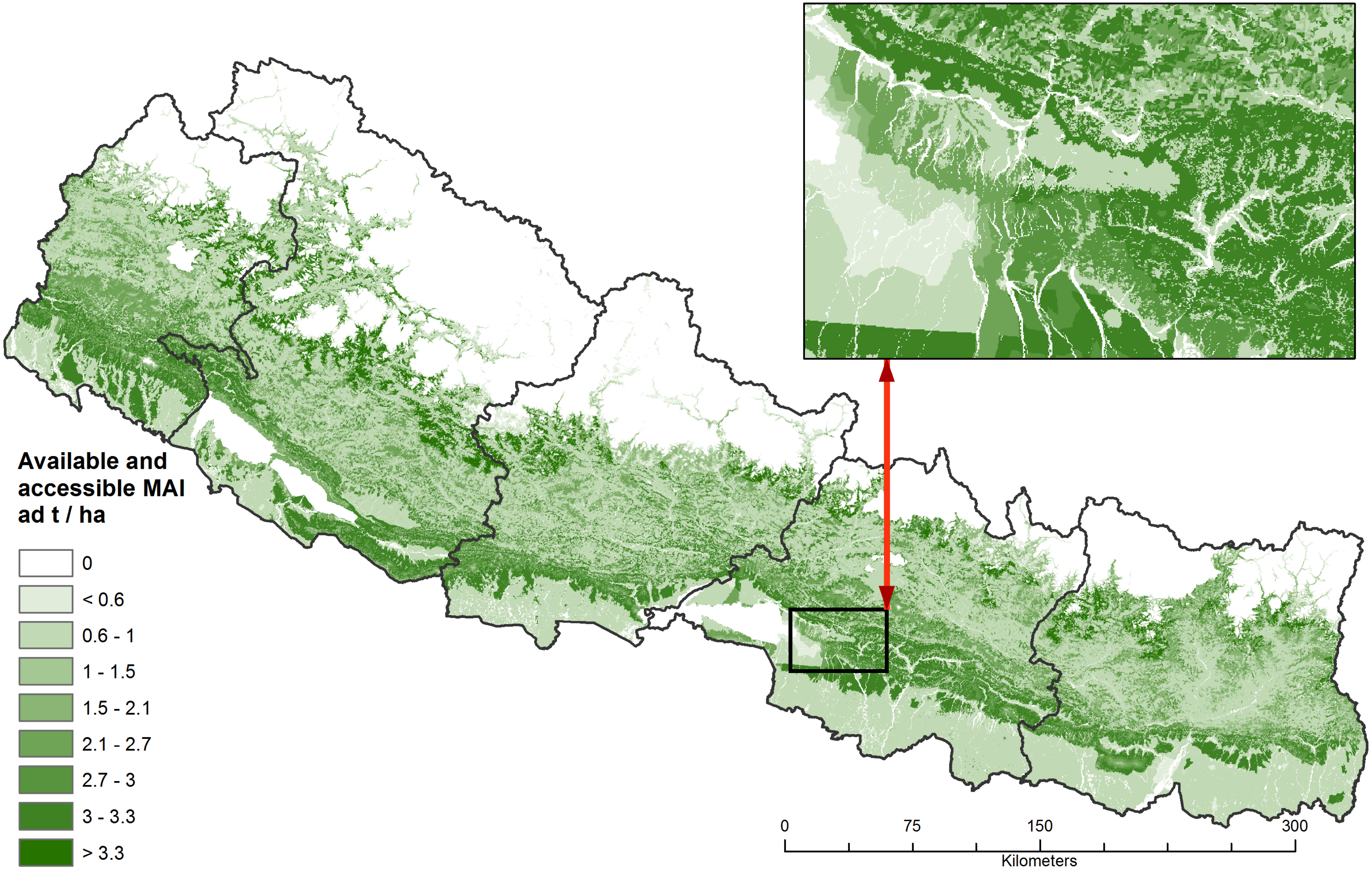


FIGURE 17

Map of pixel-level supply/demand balance.

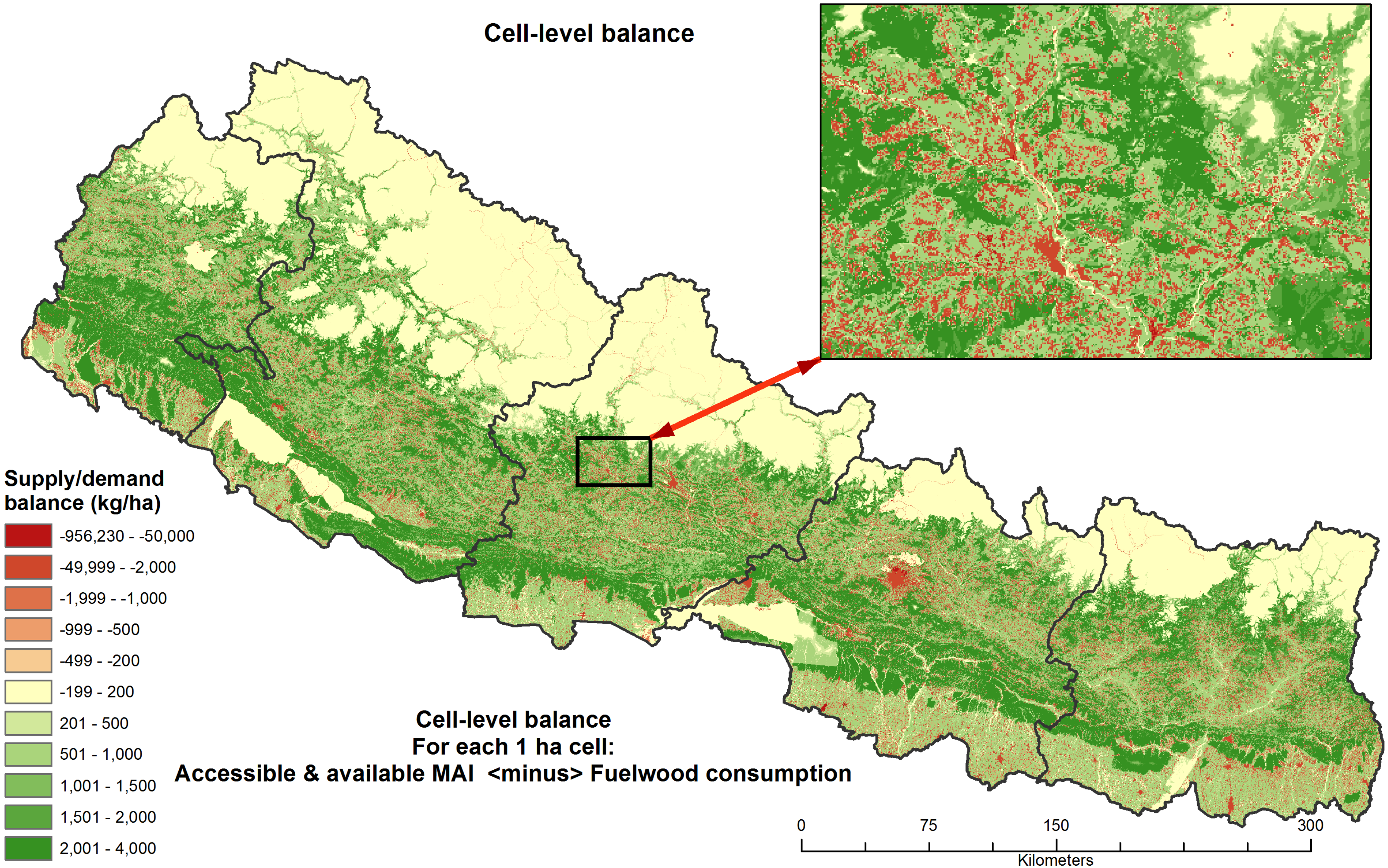


FIGURE 18

Map of Local Balance estimated within local harvesting context of 3 km

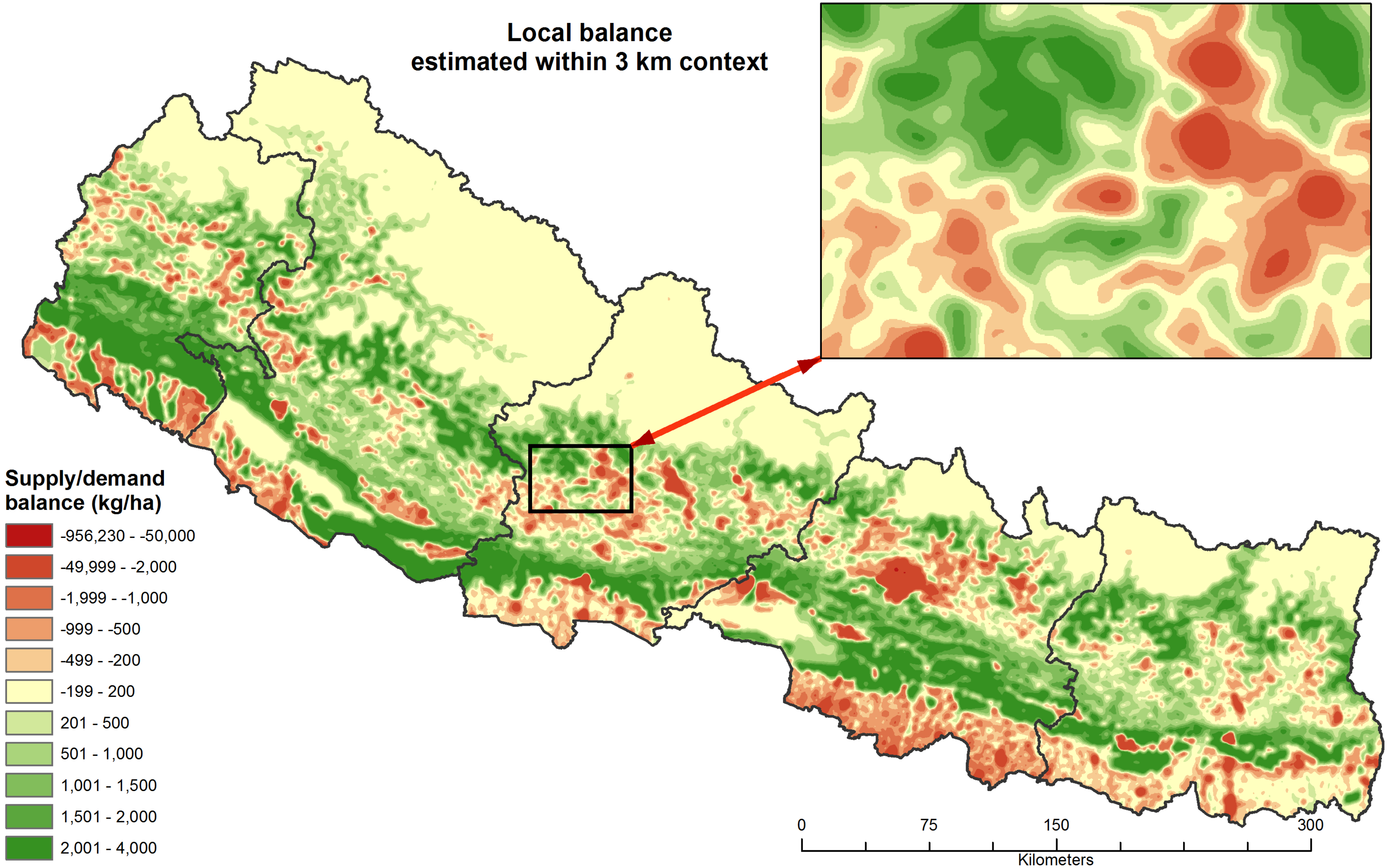


FIGURE 19

Map of commercial balance

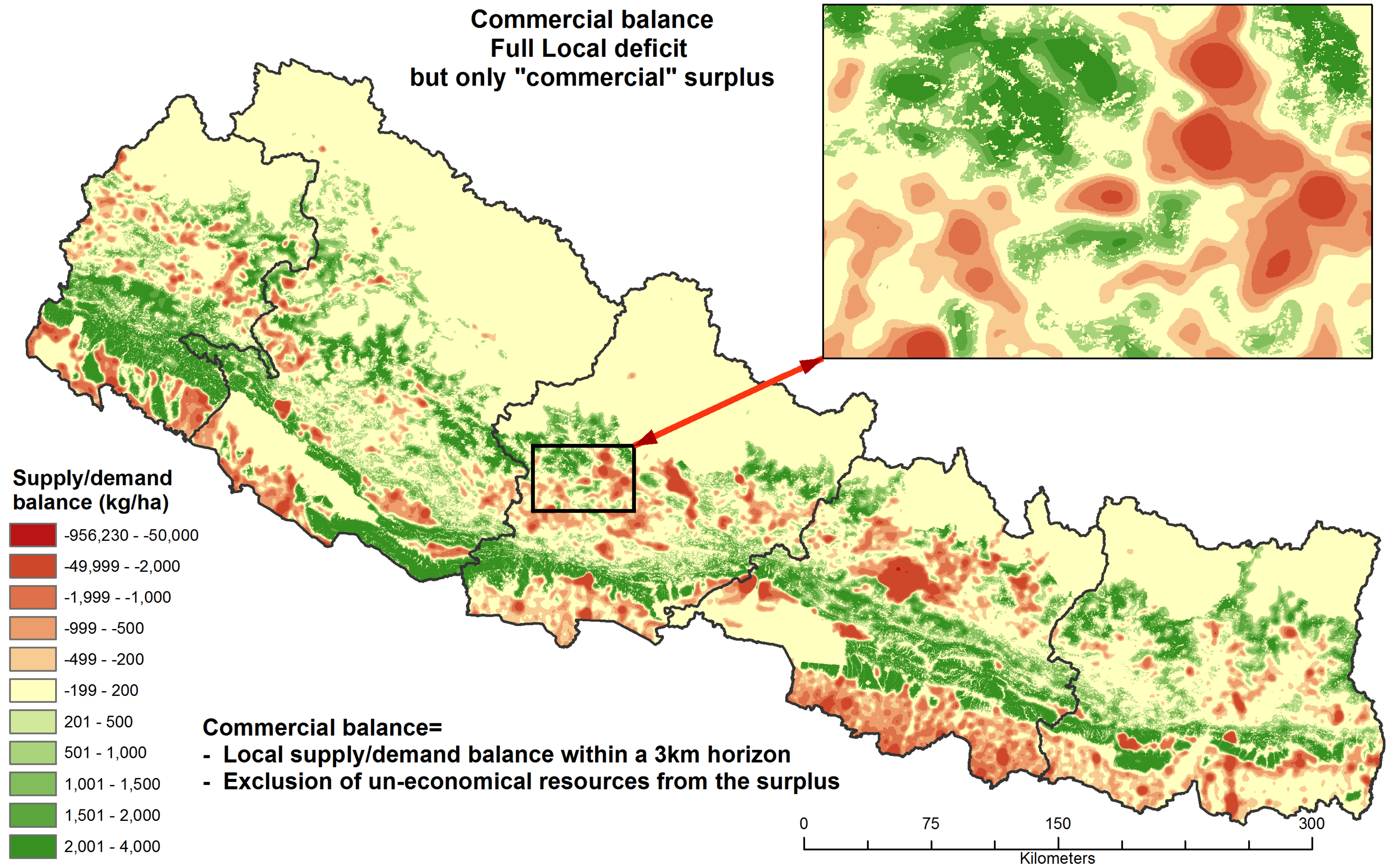


FIGURE 20

Map of harvesting pressure determined by the fuelwood demand of major deficit sites and physical accessibility.

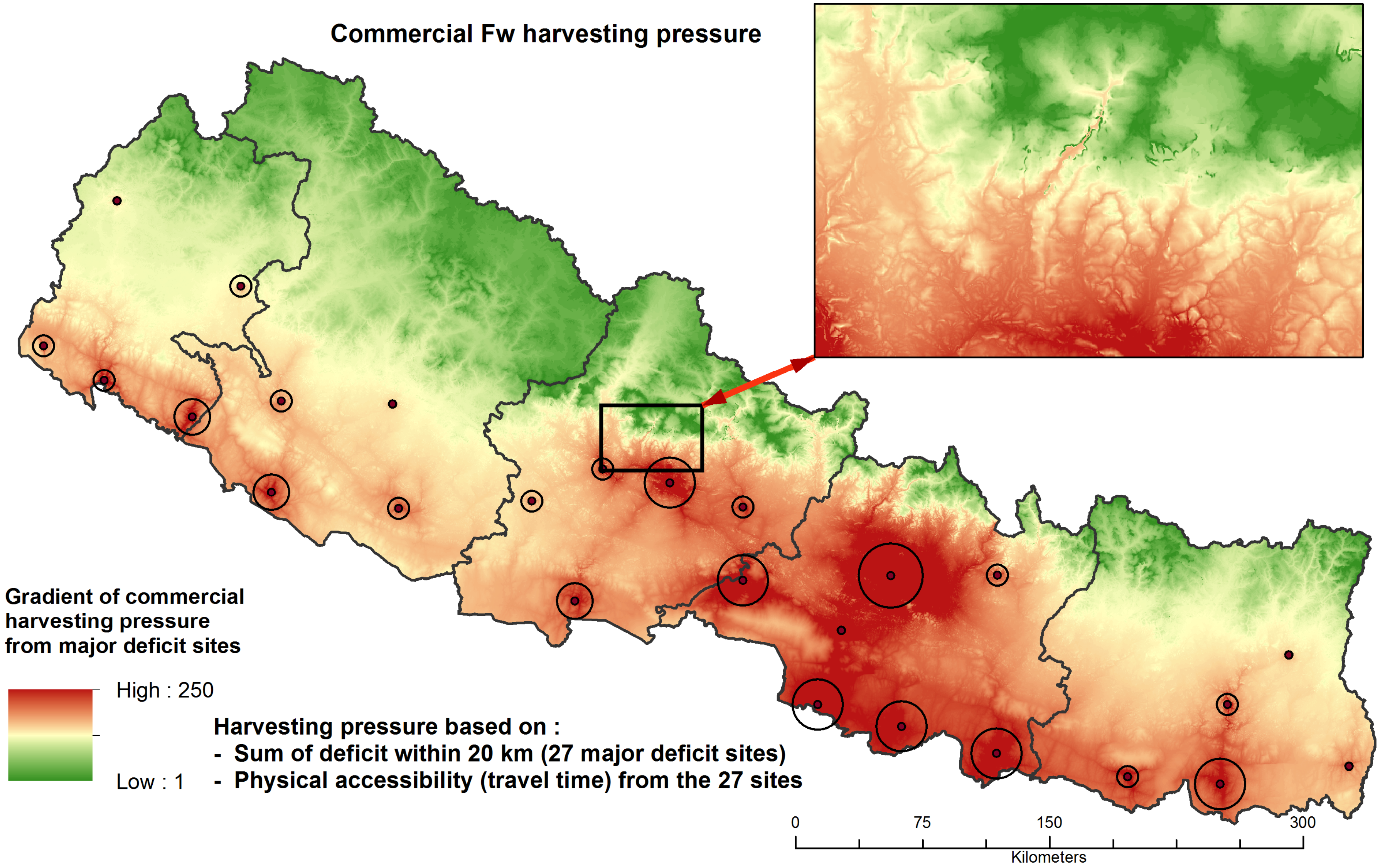


FIGURE 21

Map of probable commercial harvesting area based on demand pressure, commercial balance and a travel time threshold of 12 hours.

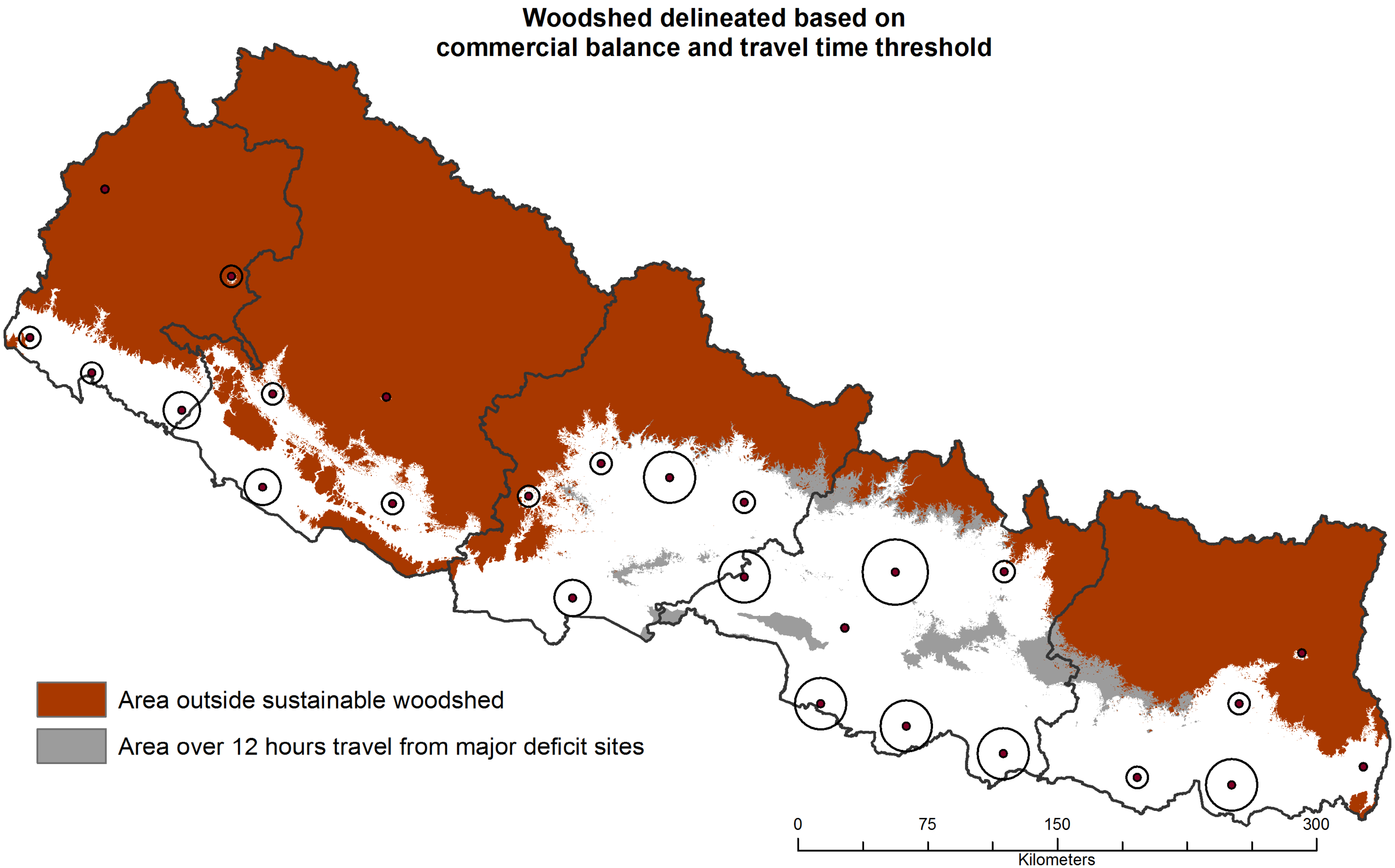


FIGURE 22

Map of commercial balance of the woodshed area within 12 hours of transport time from the major deficit sites.

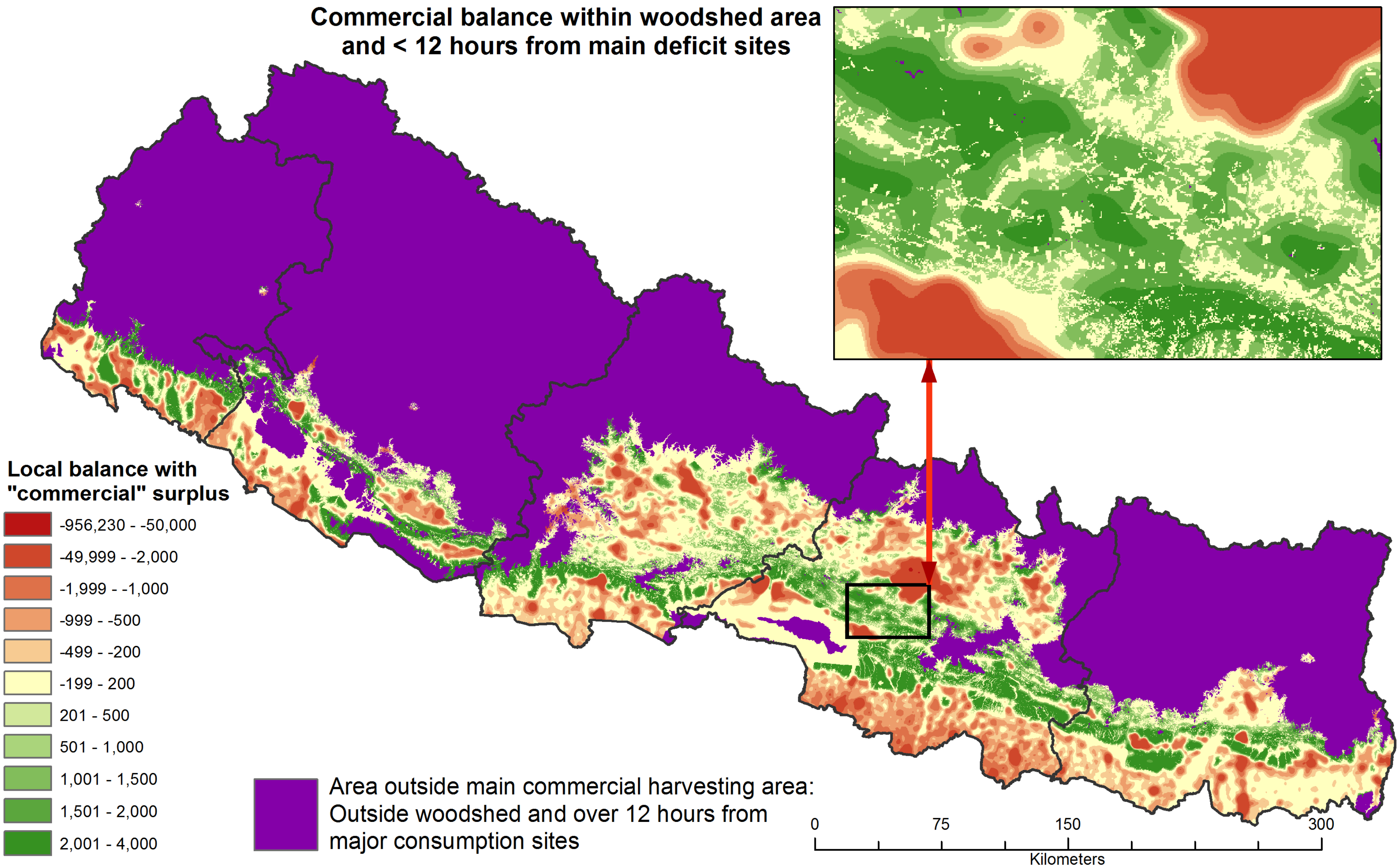


FIGURE 23

Map of probable harvesting intensity determined by projecting the fuelwood deficit onto the commercial surplus according to harvesting pressure (shown in Fig.20) and surplus level.

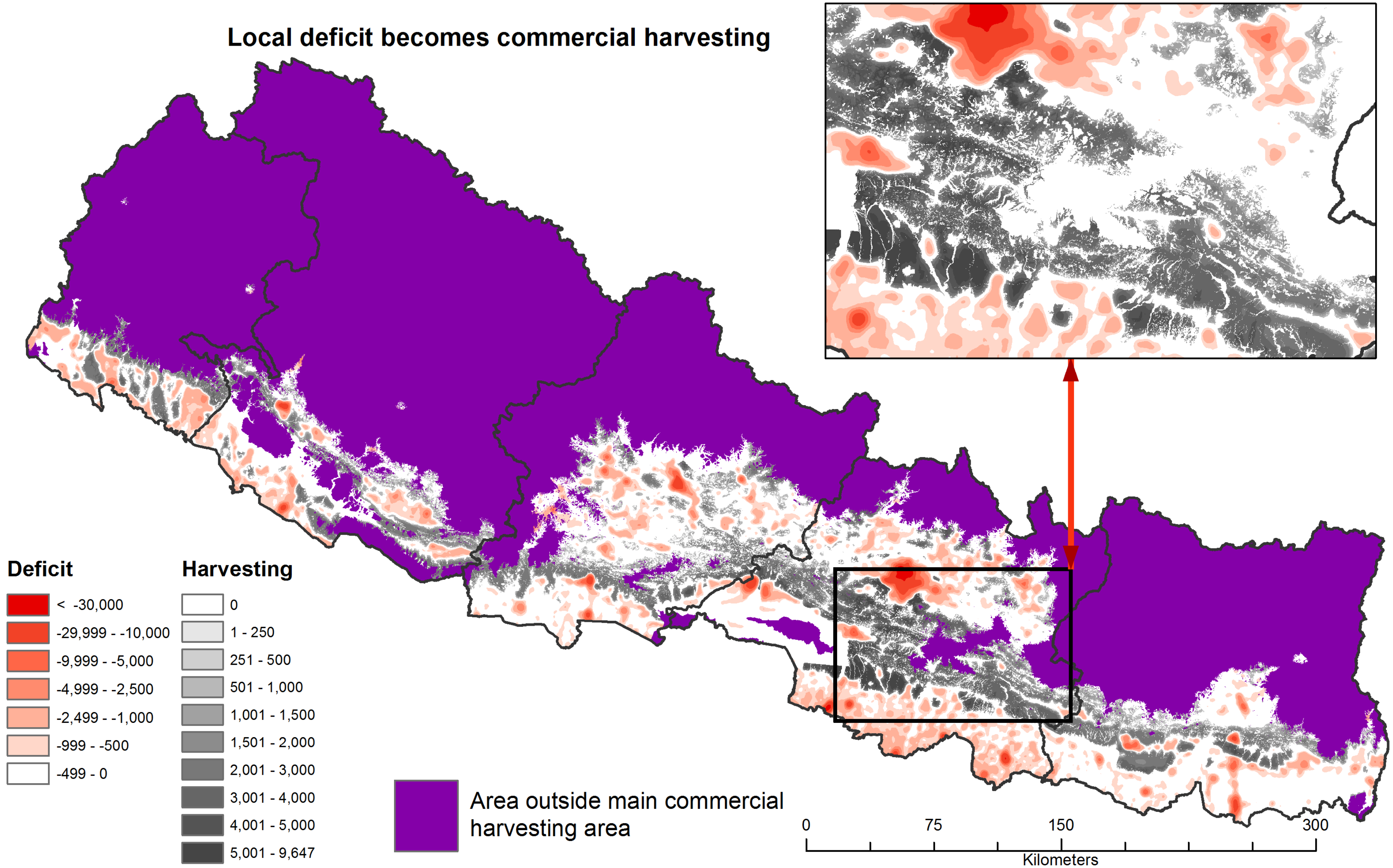


FIGURE 24

Map of the sustainability of commercial fuelwood harvesting. Negative values (in red) indicate areas where the harvesting is greater than the sustainable commercial surplus

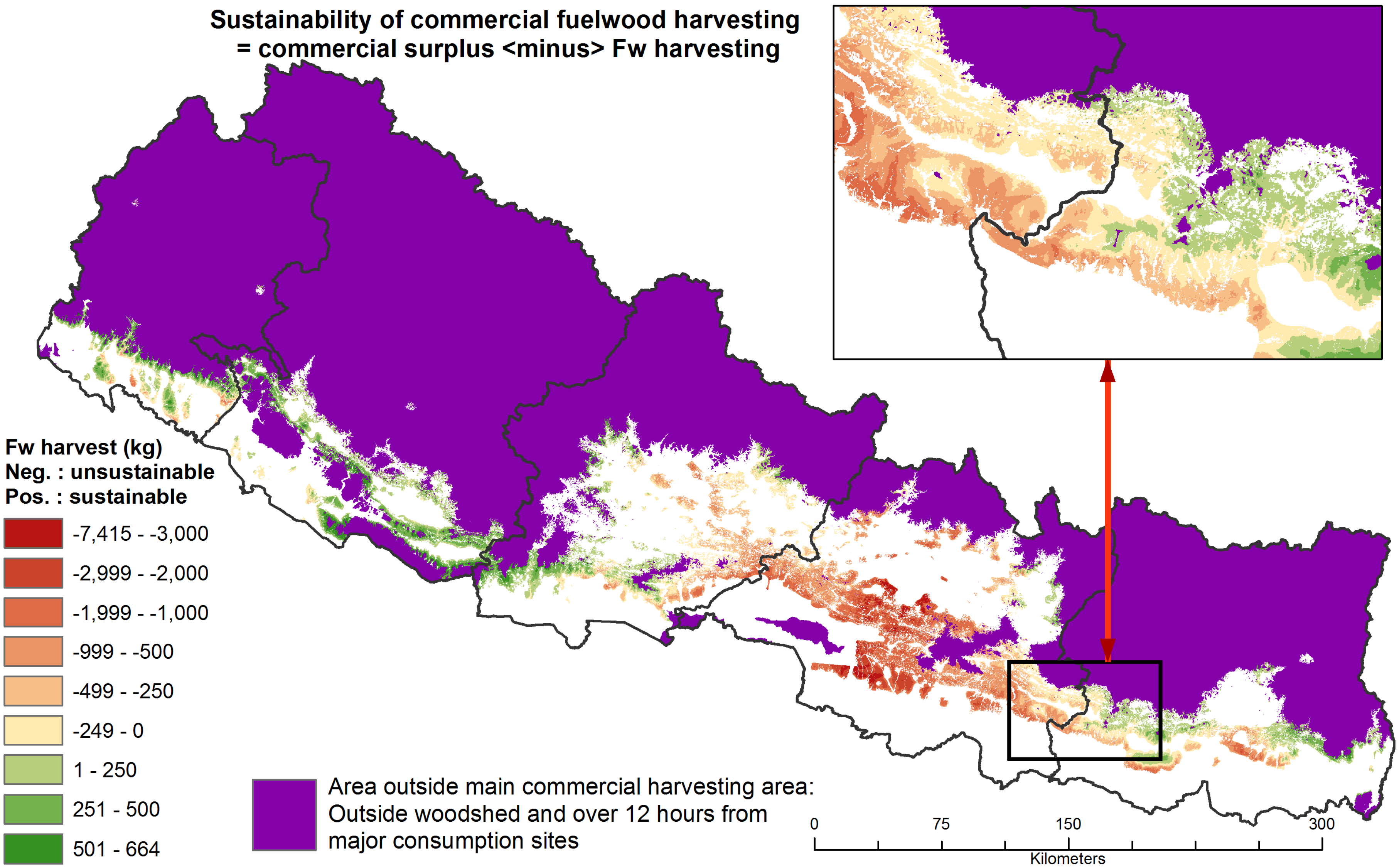
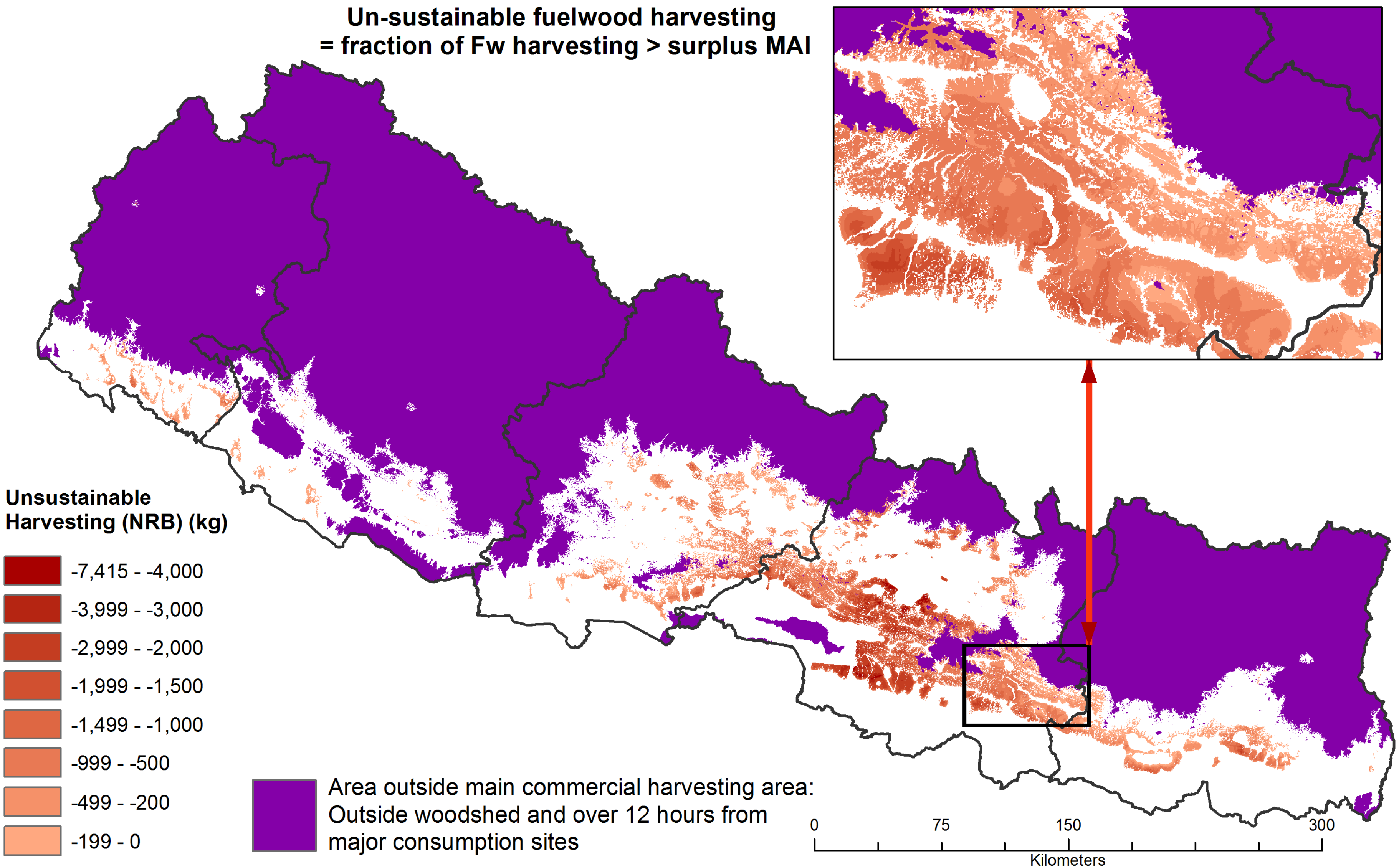


FIGURE 25

Map of probable degradation induced by excessive fuelwood harvesting.



CONCLUSIONS AND RECOMMENDATIONS

Contribution of WISDOM Nepal to MRV System

- Overall, the accessible sustainable supply potential of Nepal is greater than the demand for woody biomass for energy and for other uses. Excluding the industrial roundwood production, the supply potential is almost 16 million tons (air dry), while the demand for conventional fuelwood is 10.5 million tons, with a theoretical surplus of 5.4 million tons.
- In good part of the Country the rural demand for fuelwood seems to be satisfied by the resources accessible within the typical harvesting horizon of 3 km or within 10-15 km for the larger settlements. However, this is not the case for the Hills and Siwaliks of Central and Western Development Regions and in the densely populated Terai where the high concentration of the consumption creates a strong commercial fuelwood demand which poses a high pressure on the accessible resources with consequent risk of degradation.
- The expected impact of excessive harvesting is estimated at 758,000 tons, which represents the dimension of the expected degradation and is distributed primarily in the Hills and Siwaliks of the Central and Western Development Regions.
- This degradation rate should be considered as the expected minimum because we assumed the optimal (if not sustainable) exploitation of the accessible resources. While this assumption may be justified for the forests under community control, it may be optimistic for other areas where the exploitation is likely to be more chaotic.
- Through this analysis we estimated the risk of degradation, spatialized and quantitative, but still the risk and not the actual degradation, that remains to be assessed in the field and through multi-temporal remote sensing techniques. But the assessment of forest degradation is far more challenging, and expensive, than the assessment of deforestation both in terms of field measurements and resolution of remote sensing data.
- A key contribution of WISDOM to MRV concerning the actual assessment of forest degradation is in the stratification of forests according the risk of degradation. Such stratification allows to concentrate the high resolution observations where the phenomenon is more likely to happen, for instance through a statistically more efficient PPS approach, and thus reduce the costs of the assessment.
- Another contribution is in revealing the cause-effect mechanism behind degradation processes. Beyond measuring deforestation and degradation we need to identify remedial actions and to this end WISDOM provides essential quantitative and spatial elements linking cause (demand for fuelwood) and effect (rates of degradation) that are fundamental to the formulation of focused forestry and energy policies and the design of strategic and operational planning.

Contribution of national-level WISDOM to MRV activities in local Communities

- The national-level WISDOM provides additional elements for the selection of local Communities for detailed MRV activities on the basis of the risk of forest degradation from fuelwood harvesting
- For the selected Communities, it provides contextual settings for local MRV activities, including
  - Quantify the pressure (i.e. biomass extraction) induced by actors outside the selected Communities, such as:
    - the local demand from neighboring areas and
    - the commercial demand from distant fuelwood markets
  - Supports leakage analyses

The development of Community-level WISDOM analyses would imply the following:

- Revision of demand and supply parameters according to local conditions (high resolution maps and demand surveys)
- Revision of accessibility analysis (actual harvesting horizon)
- Delineation of actual harvesting areas (woodshed analysis) for local demand and commercial markets

Conducted at Community-level, WISDOM analyses would contribute to MRV activities through:

- Quantification of the baseline Non Renewable Biomass fraction
- Analysis of actual leakages
- Support local operational planning of sustainable wood energy systems and more in general REDD+ activities

Main conclusions on WISDOM development

The development of WISDOM Nepal implied several assumptions and some tentative value attributions to fill in for information gaps, as discussed in the previous sections. In order to improve and consolidate the knowledge base these assumption need validation and tentative estimates should be replaced by solid reference data. The most relevant information gaps to be filled in with priority include the following:

Data weakness on supply

- The land cover data used is preliminary and must be replaced by recent and reliable map with good detail on vegetation densities within and outside forests to allow biomass mapping.
- There is little data on sustainable productivity in forests and nothing at all on productivity in farmlands and shrublands. These are important sources of fuelwood that must be well understood in order to assess with accuracy the true impact on forest resources.
- The industrial roundwood production appears very low. Beyond Forest Department records on timber production and sale, the estimation of the total use of industrial roundwood in Nepal should be based on industrial sector data in consultation with the Chamber of Commerce.
- The physical accessibility of wood resources is of paramount importance in a mountain country like Nepal. Updated road network data, including non-motorable trails foothpaths is essential for a correct estimation of accessible resources.

Data weakness on demand

- Fuelwood consumption surveys must adopt quantitative measurement techniques avoiding as much as possible people's estimates of consumption per month or per year. FAO produced useful practical guidelines on fuelwood consumption surveys (FAO, 2002) that offer interesting solutions. In particular, the "average day consumption" approach seems very effective as it allows to measure a day's consumption with good accuracy with only one visit.
- Consumption surveys must differentiate “conventional” fuelwood made of stem wood and branches from “marginal” fuelwood made of twigs and smaller branches that are not considered among forest products. and that are often produced through annual or periodic pruning of farm trees and shrubs, hedges, etc..
- The coping strategies put in place by rural households in scarcity or absence of “conventional” fuelwood are little known. Annual or periodic pruning of farm trees, shrubs, hedges, etc. certainly produce more fuelwood than it is generally assumed
- The ignorance of fuelwood type, supply sources and their sustainable productivity often induce the overestimation of the impact of fuelwood on forest resources (and thus to bad policies)

Transfer and handling of the WISDOM Geo-database

The WISDOM Nepal Geo-database is part of the MRV database that will be transferred to the appropriate Government Unit upon completion of the MRV project. In addition, the most relevant results of the analysis will be uploaded for consultation and basic handling.

The list of map layers that compose the geo-database is provided in Annex 6, along with a short description of the sources and processing steps undertaken for their production. This information should be used as reference in all future handling or updating of WISDOM map layers.

Through a GIS software the data (vector and raster format) can be visualized, analyzed at different administrative levels for information to help reporting and decision making. But several levels of interaction may be envisaged. In order to guide future handling of WISDOM layers, Table 4 provides an overview of the levels of interaction that can be developed and the corresponding GIS skills required.

TABLE 4

Levels of interaction with the WISDOM datasets

Level of interactions	Description of the possible applications	Required GIS skills
Elementary Level: Extraction of statistics by sub-national units	Use administrative units boundaries to extract statistics from raster datasets containing spatial statistics of supply and demand	Basic skills of GIS and geoprocessing tools such as Zonal Statistics
Medium Level: Production of thematic maps for selected locations or sub-national units	With the results of the extracted statistics, select the location or sub-national unit by the required techniques (select by attribute, select by location, for vector layer, or masking the selected unit in case of raster); layout map preparation	Moderate skills in GIS and geoprocessing tools
Advanced Level: Change of demand or supply parameters and re-running of WISDOM analysis	Change the parameters settings of the supply or demand according to new information; re-run the geoprocessing tools or models to process new demand or supply raster datasets	Advanced skills of WISDOM concepts (Expert), advanced knowledge of GIS and geoprocessing

The entire WISDOM analysis was carried out with the involvement and active participation of MRV Project staff. The knowledge acquired by National MRV staff represents a precious asset for future handling of WISDOM data in Nepal and for providing elemental training to the personnel of the recipient Government Unit. It should be emphasized, however, that the counterpart designated to manage the WISDOM data must have advanced GIS skills, especially concerning the processing of raster data.

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ANNEXES

ANNEX 1: FUEL SATURATION IN RESIDENTIAL SECTOR (% USERS)

CBS NLSS 2010 - Percent saturation cooking fuel

stratum	Firewood	Leaves/rubbish/straw/thatch	Dung	Bio-gas	Cylinder gas	Kerosene	Other	Total HH
Urban-Kathmandu Valley	**2.9**	0.7	0.0	0.0	92.8	3.2	0.4	3593
Urban-Terai	**46.4**	5.2	6.8	4.2	34.9	0.4	2.1	3240
Urban-Hill	**46.4**	0.2	0.4	8.0	43.7	0.5	0.9	2043
Rural-Terai-Far-Western	**92.3**	0.0	0.5	5.4	1.8	0.0	0.0	826
Rural-Terai-Mid-Western	**85.0**	0.0	0.9	7.3	5.7	0.0	1.0	1158
Rural-Terai-Western	**42.3**	4.1	38.5	4.6	9.1	0.3	1.2	1999
Rural-Terai-Central	**53.0**	13.1	28.4	3.0	2.1	0.1	0.4	2701
Rural-Terai-Eastern	**39.4**	7.9	40.5	5.1	6.5	0.0	0.6	2354
Rural-Hill-Far-Western	**99.1**	0.0	0.9	0.0	0.0	0.0	0.0	892
Rural-Hill-Mid-Western	**96.5**	0.0	0.2	0.9	2.5	0.0	0.0	1749
Rural-Hill-Western	**90.3**	0.2	0.5	4.6	4.0	0.0	0.4	2041
Rural-Hill-Central	**79.6**	0.9	0.1	1.7	16.8	0.2	0.7	2256
Rural-Hill-Eastern	**98.4**	0.4	0.4	0.5	0.3	0.0	0.0	1827
Mountain	**91.9**	0.0	0.4	0.4	6.6	0.4	0.3	1991
Total	**60.5**	**3.0**	**9.7**	**3.1**	**22.6**	**0.6**	**0.7**	**28670**

Per capita consumption in **rural areas** (ad kg / person / year)

	REGI_NAME	MPFS 1988	Fox (1984)	Source: Rijal (2002)	CBS_NLSS2010	average weighted on Fw users
Terai	Far-Western	479			546	514
	Mid-Western					
	Western	482		535		
	Central	474				
	Eastern	483				
Hills	Far-Western	548	511		691	610
	Mid-Western					
	Western	743		348		
	Central	484		561		
	Eastern	829				
Mountains	Far-Western	548			707	781
	Mid-Western					
	Western	743				
	Central	484				
	Eastern	829		1130		

Per capita consumption in **urban areas** (ad kg / person / year)

<table>
<tr><th></th><th>REGI_NAME</th><th>MPFS
1988</th><th>Source: Rijal
(2002)</th><th>CBS_NLSS2010</th><th>based on rural HH less farming uses.
applied to users only</th></tr>
<tr><td rowspan="5">Terai</td><td>Far-Western</td><td rowspan="15">248
(applied to tot urban pop)</td><td rowspan="8"></td><td rowspan="15">162 Kathmandu

589 elsewhere</td><td rowspan="5">407</td></tr>
<tr><td>Mid-Western</td></tr>
<tr><td>Western</td></tr>
<tr><td>Central</td></tr>
<tr><td>Eastern</td></tr>
<tr><td rowspan="5">Hills</td><td>Far-Western</td><td rowspan="5">483</td></tr>
<tr><td>Mid-Western</td></tr>
<tr><td>Western</td></tr>
<tr><td>Central</td><td>235</td></tr>
<tr><td>Eastern</td><td rowspan="6"></td></tr>
<tr><td rowspan="5">Mountains</td><td>Far-Western</td><td rowspan="5">619</td></tr>
<tr><td>Mid-Western</td></tr>
<tr><td>Western</td></tr>
<tr><td>Central</td></tr>
<tr><td>Eastern</td></tr>
</table>

ANNEX 2: STOCK AND MAI OF MAIN LAND COVER CLASSES

DESCRIPTIO	NEW_LCOVER	Icimod LC_Class	AGB ad t_ha	DE_Biomass ad t_ha	MAI_DEB percent	MAI_DEB ad kg_ha_yr
High Mountain	Forest	Undefined	149.3	121.1	2.2	2675
High Mountain	Forest	Needleleaved Open Forest	161.3	130.8	1.9	2509
High Mountain	Forest	Broadleaved Open Forest	126.9	102.9	2.4	2502
High Mountain	Other Wooded	Needleleaved	30	24.3	4.5	1094
High Mountain	Other Wooded	Broadleaved	30	24.3	5.7	1381
High Mountain	Other	Shrubland	10	8.1	10.8	878
High Mountain	Other	Grassland	4	3.2	18.6	602
High Mountain	Other	Bare Area	0	0.0		
Middle Mountain	Forest	Undefined	288	233.6	1.5	3507
Middle Mountain	Forest	Needleleaved Closed Forest	392.5	318.3	1.2	3889
Middle Mountain	Forest	Needleleaved Open Forest	154.7	125.5	2.0	2457
Middle Mountain	Forest	Broadleaved Closed Forest	277.1	224.7	1.5	3451
Middle Mountain	Forest	Broadleaved Open Forest	179.1	145.3	2.0	2883
Middle Mountain	Other Wooded	Needleleaved	30	24.3	4.5	1094
Middle Mountain	Other Wooded	Broadleaved	30	24.3	5.7	1381
Middle Mountain	Other	Grassland	4	3.2	18.6	602
Middle Mountain	Other	Agriculture	10	8.1	10.8	878
Middle Mountain	Other	Bare Area	0	0.0		
Hill	Forest	Undefined	181	146.8	2.0	2896
Hill	Forest	Needleleaved Closed Forest	172.2	139.7	1.9	2591
Hill	Forest	Needleleaved Open Forest	92.4	74.9	2.5	1906
Hill	Forest	Broadleaved Closed Forest	215.8	175.0	1.8	3114
Hill	Forest	Broadleaved Open Forest	92	74.6	2.9	2191
Hill	Other Wooded	Needleleaved	30	24.3	4.5	1094
Hill	Other Wooded	Broadleaved	30	24.3	5.7	1381
Hill	Other	Grassland	4	3.2	18.6	602
Hill	Other	Agriculture	10	8.1	10.8	878
Hill	Other	Bare Area	0	0.0		
Siwalik	Forest	Needleleaved Closed Forest	165.5	134.2	1.9	2541
Siwalik	Forest	Needleleaved Open Forest	51.5	41.8	3.4	1429
Siwalik	Forest	Broadleaved Closed Forest	227.4	184.4	1.7	3181
Siwalik	Forest	Broadleaved Open Forest	131	106.2	2.4	2535
Siwalik	Forest	Undefined	215	174.4	1.8	3109
Siwalik	Other Wooded	Needleleaved	30	24.3	4.5	1094
Siwalik	Other Wooded	Broadleaved	30	24.3	5.7	1381
Siwalik	Other	Agriculture	10	8.1	10.8	878
Siwalik	Other	Bare Area	0	0.0		
Siwalik	Other	Builtup Area	4	3.2	18.6	602
Terai	Forest	Needleleaved Open Forest	238	193.0	1.6	3039
Terai	Forest	Broadleaved Closed Forest	238	193.0	1.7	3242
Terai	Other	Agriculture	10	8.1	10.8	878
Terai	Other	Bare Area	0	0.0		
Terai	Other	Builtup Area	4	3.2	18.6	602

ANNEX 3: INDUSTRIAL ROUNDWOOD PRODUCTION

Based on recorded Timber Sale by district-2010/11

Dist. code	District	Recorded timber volumes by FD and by Gov.t of Terai and Inner Terai			Estimated 20% unrecored in Hills and Terai	Tot estimated timber extraction
		cft	m3	ad t	ad t	ad t
1	Taplejung	23087	654	458	92	**549**
2	Panchthar	641349	18,161	12,713	2,543	**15,255**
3	Ilam	67214	1,903	1,332	266	**1,599**
4	Jhapa	188222	5,330	3,731	746	**4,477**
5	Morang	221094	6,261	4,382	876	**5,259**
6	Sunsari	57917	1,640	1,148	230	**1,378**
7	Dhankuta	934119	26,451	18,516	3,703	**22,219**
8	Terhathum	373395	10,573	7,401	1,480	**8,882**
9	Sankhuwasabha	100478	2,845	1,992	398	**2,390**
10	Bhojpur	0	0	0	0	**0**
11	Solukhumbu	0	0	0	0	**0**
12	Okhaldhunga	0	0	0	0	**0**
13	Khotang	0	0	0	0	**0**
14	Udayapur	77567	2,196	1,538	308	**1,845**
15	Saptari	299	8	6	1	**7**
16	Siraha	44920	1,272	890	178	**1,068**
17	Dhanusa	3628	103	72	14	**86**
18	Mahottari	19927	564	395	79	**474**
19	Sarlahi	69464	1,967	1,377	275	**1,652**
20	Sindhuli	91406	2,588	1,812	362	**2,174**
21	Ramechhap	0	0	0	0	**0**
22	Dolakha	237317	6,720	4,704	941	**5,645**
23	Sindhupalchok	0	0	0	0	**0**
24	Kavrepalanchok	0	0	0	0	**0**
25	Lalitpur	0	0	0	0	**0**
26	Bhaktapur	0	0	0	0	**0**
27	Kathmandu	0	0	0	0	**0**
28	Nuwakot	0	0	0	0	**0**
29	Rasuwa	0	0	0	0	**0**
30	Dhading	32536	921	645	129	**774**
31	Makwanpur	35317	1,000	700	140	**840**
32	Rautahat	172582	4,887	3,421	684	**4,105**
33	Bara	568501	16,098	11,269	2,254	**13,522**
34	Parsa	16341	463	324	65	**389**
35	Chitawan	529390	14,991	10,493	2,099	**12,592**
36	Gorkha	26034	737	516	103	**619**
37	Lamjung	37035	1,049	734	147	**881**
38	Tanahu	0	0	0	0	**0**
39	Syangja	24363	690	483	97	**580**
40	Kaski	0	0	0	0	**0**
41	Manang	0	0	0	0	**0**
42	Mustang	0	0	0	0	**0**
43	Myagdi	9338	264	185	37	**222**
44	Parbat	0	0	0	0	**0**
45	Baglung	23531	666	466	93	**560**
46	Gulmi	0	0	0	0	**0**
47	Palpa	0	0	0	0	**0**
48	Nawalparasi	175591	4,972	3,481	696	**4,177**
49	Rupandehi	89885	2,545	1,782	356	**2,138**
50	Kapilbastu	82145	2,326	1,628	326	**1,954**

Dist. code	District	Recorded timber volumes by FD and by Gov.t of Terai and Inner Terai			Estimated 20% unrecored in Hills and Terai	Tot estimated timber extraction
		cft	m3	ad t	ad t	ad t
51	Arghakhanchi	228375	6,467	4,527	905	**5,432**
52	Pyuthan	0	0	0	0	**0**
53	Rolpa	0	0	0	0	**0**
54	Rukum	6783	192	134	27	**161**
55	Salyan	0	0	0	0	**0**
56	Dang	4149	117	82	16	**99**
57	Banke	153712	4,353	3,047	609	**3,656**
58	Bardiya	31246	885	619	124	**743**
59	Surkhet	17365	492	344	69	**413**
60	Dailekh	13739	389	272	54	**327**
61	Jajarkot	0	0	0	0	**0**
62	Dolpa	0	0	0	0	**0**
63	Jumla	0	0	0	0	**0**
64	Kalikot	0	0	0	0	**0**
65	Mugu	0	0	0	0	**0**
66	Humla	0	0	0	0	**0**
67	Bajura	0	0	0	0	**0**
68	Bajhang	0	0	0	0	**0**
69	Achham	0	0	0	0	**0**
70	Doti	0	0	0	0	**0**
71	Kailali	220657	6,248	4,374	875	**5,249**
72	Kanchanpur	40573	1,149	804	161	**965**
73	Dadeldhura	260	7	5	1	**6**
74	Baitadi	0	0	0	0	**0**
75	Darchula	908	26	18	4	**22**
	Total	**5,691,759**	**161,173**	**112,821**	**22,564**	**135,385**

ANNEX 4: LEGAL ACCESSIBILITY OF BIOMASS RESOURCES

Preliminarily, we assume all woody biomass is legally accessible with the exception of resources found within protected areas, which face some restrictions.

In reality, National Parks and other conservation areas present various restrictions on the exploitation of forest resources. In order to account for these legal constraints, an accessibility factor was allocated to the protected areas on the basis of IUCN definitions of Protected Area Management Categories and on national experts' opinions on the access rates (percent accessible) of biomass resources to local communities and to commercial operators in each protection category. The Map of protected areas of Nepal (file Nat_parks_MRV_Db from MRV_Database) is more detailed and more complete than the dataset published by WCMC-IUCN and is therefore used as main reference.

The estimated accessibility for fuelwood harvesting for local and commercial use is shown in Table A4.1. The maps showing the corresponding areas are presented in Figure A4.1. All protected areas (including buffer zones) are 0% accessible for commercial production of fuelwood.

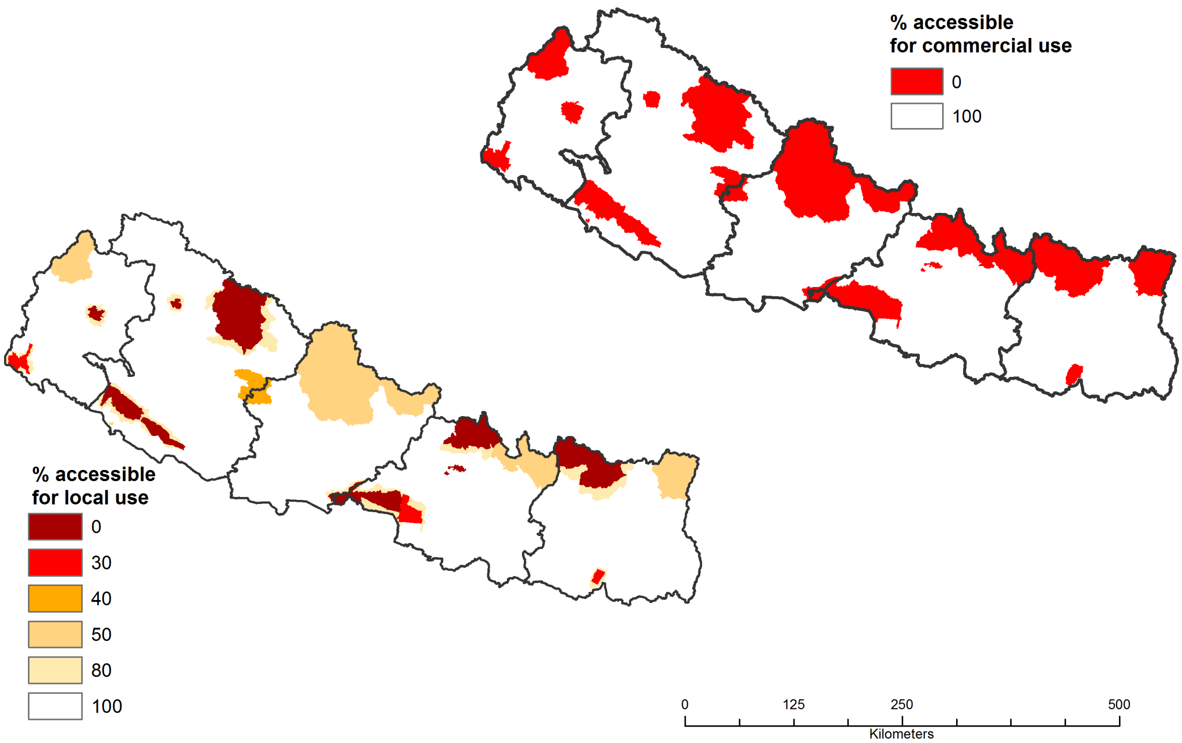
TABLE A4.1

Categories of Protected Areas of Nepal and their assumed accessibility for local and for commercial fuelwood production

Protected areas	Area (ha)	For Local Use:	For Commercial Use:
National Parks	1,083,202	0 %	0 %
Wildlife Reserves	109,989	30 %	0 %
Hunting Reserves	119,247	40 %	0 %
Conservation Areas	1,551,873	50 %	0 %
Buffer zones of NP, WR and CAs	575,677	80 %	0 %

FIGURE A4.1

Distribution of protected areas and their assumed accessibility for local and for commercial fuelwood production



ANNEX 5: PHYSICAL ACCESSIBILITY OF BIOMASS RESOURCES

Off-road accessibility-Travel time to nearest access feature (city, populated area, motorable road, cart tract)

Assuming that the resources that are located along communication routes (motorable roads and cart tracts - there are no navigable rivers and railway is negligible-) or that are close to populated places (urban centres, villages and densely populated rural areas) have highest accessibility, it may be assumed that the accessibility of the resources located far from such features are inversely proportional to the time (or effort) necessary to reach them (considering here the time needed to go and return with fuelwood load).

In order to associate a parameter of physical accessibility to the legally-accessible woody biomass resources, a **fuelwood transport time map** is produced following and adapting the procedure described by Nelson[4] and by Drigo[5] . The specific features of the Nepal study include a redefinition of the target locations based on the most detailed available national maps (road, tracts, trail and footpaths; buildings and builtup areas), the use of 30m elevation model and of best available land cover data, and the adaptation of friction factors and slope factors to Nepali situation.

Target locations

The target locations are all accessible areas, including:

1. Populated places,:
   a. Urban areas. Map name **built_4mn** . The speed of 15 km/hr = 4 min/km assumed for urban transport assumed.
   b. Densely populated rural areas. Defined as rural areas with population density above 178 inh. $km^{2\ -1}$, as average of surrounding 3 cells (300 m radius). With such population density, the biomass resources that still exist are assumed to be totally accessible (unless protected by law) independently from the presence of a road network. The mask of the densely populated rural areas is **pop178_16mn**, derived from the map pop_f3mean. The value is 16 for the 16min/km assumed [double speed than for cultivated area in consideration of the expected high density of paths and roads])
2. Communication features:
   a. Road network (map: road4_mnts), composed by:
      i. Metalled motorable road
      ii. Secondary motorable road
      iii. Cart track
      iv. Main trail
   b. Railways (not relevant in Nepal)

The target locations (or source features of cost-distance analysis) is composed by the layers described above, merged into a single map.

Friction surface components

Land cover friction

The base friction values applied to land cover classes and communication features, intended as transport speed in minutes per km assuming flat terrain and altitude below 2000 msl are reported in Table A5.

[4] Nelson, A. (2008) Estimated travel time to the nearest city of 50,000, or more people in year 2000. Global Environment Monitoring Unit - Joint Research Centre of the European Commission, Ispra Italy. Available at http://bioval.jrc.ec.europa.eu/products/gam/index.htm

[5] Pan-tropical map of accessibility by R. Drigo for the YALE-GACC Tier I analysis of woodfuels supply and demand. In progress.

TABLE A5.1

Friction values (minutes / km return trip) applied to land cover classes and communication features, assuming flat terrain and altitude below 2000 msl

	NEW_LCOVER	Icimod LC_Class	Going m/km	loaded factor	Return loaded	tot return trip min/km
Land cover	Forest	- all classes -	30	1.5	45	**75**
	Other Wooded	- all classes -	20	1.5	30	**50**
	Other	River and lake	60	1	60	**120**
	Other	Snow/Glacier	30	2	60	**90**
	Other	Grassland	18	1.5	27	**45**
	Other	Agriculture	16	1.5	24	**40**
	Other	Bare Area	16	1.5	24	**40**
	Other	Builtup Area	4	1.5	6	**10**
	No data	River	60	1	60	**120**
	No data	- all other classes -	16	1.5	24	**40**
Target location layers	Builtup areas		4	1	4	**8**
	Densely populated rural areas		8	1	8	**16**
	Metalled motorable road		**2**	1	2	**4**
	Secondary motorable road		**4**	1	4	**8**
	Cart track		**6**	1	6	**12**
	Main trail		**10**	1	10	**20**
Other features	Footpath		**12**	1.33	16	**28**
	Railway		**4**	1	4	**8**

Elevation factor

A speed reduction factor is applied to higher elevation starting from elevations greater than 2000 msl, as done by Nelson. Since the original factor reported in Nelson's documentation appears too abrupt (the speed gradient at 2000 m elevation suddenly lowers to only 7% of the speed below 2000 m), the speed factor calculation was therefore revised as shown in Table A5.2 to provide a smoother speed reduction progression.

Map of the travel time increase induced by altitude (1 / speed factor)

elev_fact = `Con("aster100" > 2000,1 / (Power(0.132, 0.00048*"aster100") * 7),1)`

TABLE A5.2

Crossing time factors based on altitude

	Nelson's factor f=0.15^(0.0007*Elevation(m))	Nepal case study f=7*(0.132^(0.00048*Elevation(m)))	
Altitude	f	speed factor	crossing time factor (1/speed factor)
below 2000		1.000	1.00
2000	0.070	1.00	1.00
2100	0.061	0.91	1.10
2200	0.054	0.82	1.21
2500	0.036	0.62	1.62
2750	0.026	0.48	2.07
3000	0.019	0.38	2.64
3250	0.013	0.30	3.36
3500	0.010	0.23	4.29
4000	0.005	0.14	6.97
4500	0.003	0.09	11.34
5000	0.001	0.05	18.43
6000	0.000	0.02	48.71
7000	0.000	0.01	128.76
8000	0.000	0.00	340.33

Slope factor

The slope map was produced on the basis of the Digital Elevation Model of 30m spatial resolution (source: ASTER). The effect of slope on travel speed is estimated following Nelson's approach, which was based on van Wagtendonk and Benedict (1980)[6] and is computed as follows: **v = v0e-ks** , where:

v = off road foot based velocity over the sloping terrain,
v0 = the base speed of travel over flat terrain, 5km/hr in this case,
s = slope in gradient (metres per metre) and,
k = a factor which defines the effect of slope on travel speed

For the Nepali case study a base walking speed of 5km/hr and k = 2.0 were assumed (and constant for uphill and downhill travel). The velocities over the slope grid were computed and then converted into a friction factor by dividing the base speed by the slope speed. This was then used as a multiplier against foot-based travel components (map = **slope_fact**). The estimated effect of slope on off-road speed and on crossing time are shown in Table A5.3.

TABLE A5.3

Effect of slope on off-road speed and on crossing time

slope %	gradient meter per meter	crossing time factor	speed decrease factor
0	0	1.00	1.00
1	0.01	1.03	0.95
2	0.02	1.07	0.91
5	0.05	1.17	0.79
10	0.1	1.38	0.62
15	0.15	1.62	0.48
20	0.2	1.90	0.38
25	0.25	2.24	0.30
30	0.3	2.63	0.23
35	0.35	3.09	0.18
40	0.4	3.62	0.14
45	0.45	4.26	0.11
50	0.5	5.00	0.09
60	0.6	6.90	0.06
70	0.7	9.52	0.03
80	0.8	13.13	0.02
90	0.9	18.12	0.01
100	1	25.00	0.01
200	2	625.00	0.00

Cost-distance analysis

The cost feature is represented by the cell crossing friction (in minutes per km) resulting from the combination of the friction surface components described above, as follows:
cross_mkm (float) = " frict_all_mkm " * " slope_fact " * "elev_fact"

cross_mkm / 1000 = cros_m_m = (friction as minutes/meter)

Off-road travel time to nearest accessible feature resulting from cost-distance analysis (minutes):

Source: **target**; Cost: **cros_m_m** = **cd_min**

Results of travel time

The results of the analysis are presented in Figure A5.2 that shows the map of travel time to nearest accessible

[6] van Wagtendonk, J. W. and Benedict, P. R. 1980. Travel time variation on backcountry trails. Journal of Leisure Research 12 (2): 99-106.

feature (hours of transport, return trip).

FIGURE A5.1

Friction and target features

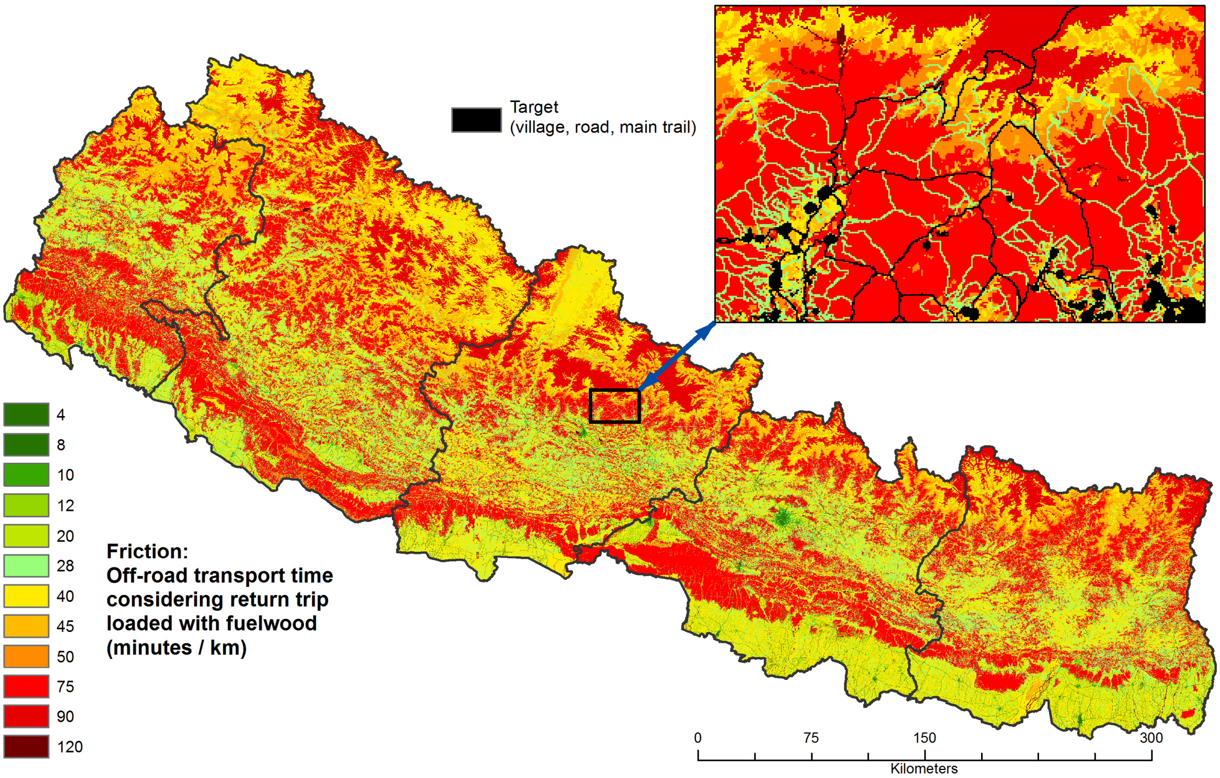
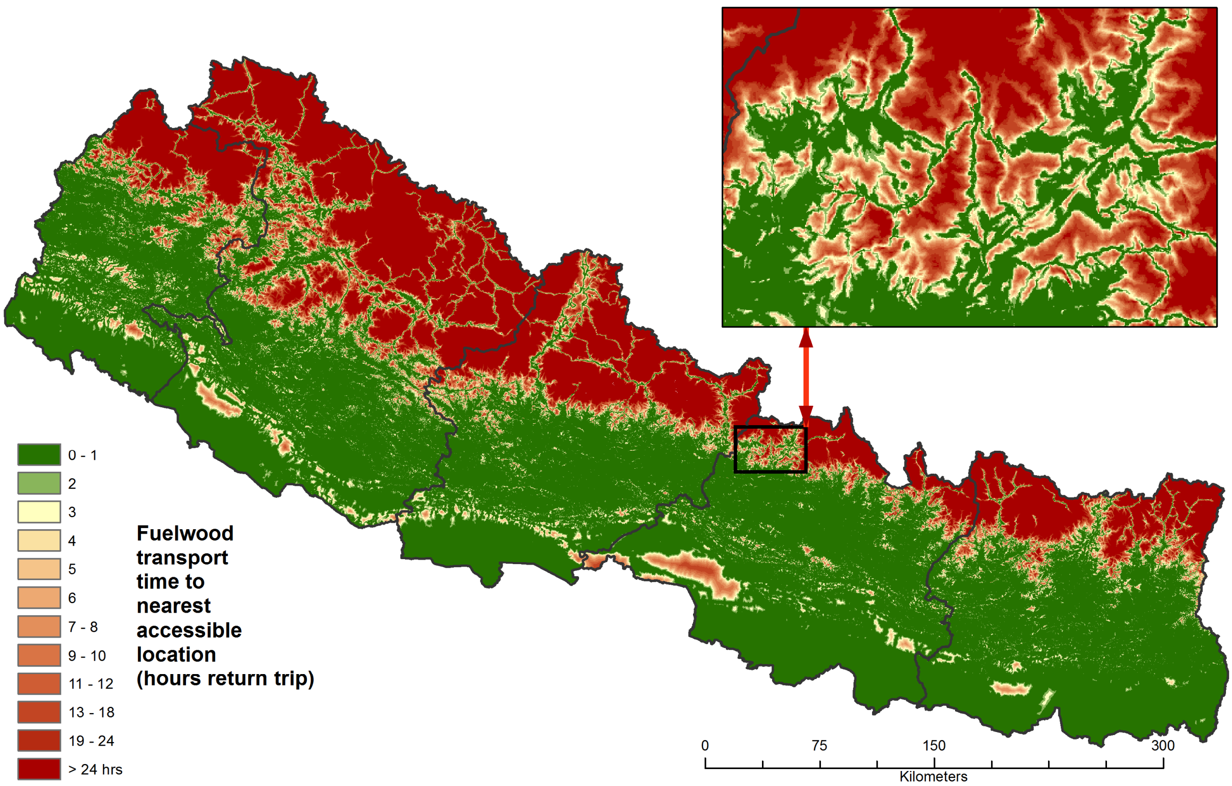


FIGURE A5.2

Fuelwood transport time map (hours from the nearest target feature)



Accessibility

The next fundamental step of analysis is to develop a map of accessibility based on the travel time map that help to assess what fraction of the existing (and legally accessible) DEB resources may be considered as truly accessible.

The conversion of travel time to percent of accessibility is based on the hypothesis that resources further than 10 hours off-road transport time to the nearest accessible feature are non accessible. Table A.5.4 presents the hypothesis of conversion of travel time into percent of accessibility applied, by which 84.1 % of all resources are physically accessible and 15.9 inaccessible.

TABLE A5.4

Hypotheses of accessibility factors to be applied to estimate DEB resources based on travel time (ref. cd_02_clip)

					Non-accessible MAI (%) :		**15.9**
					Accessible MAI (%) :		**84.1**
	Transport time from nearest target feature						accessible MAI
cd2_20	minutes	hours	work days	**MAI ktad**	access loss (%)	% accessible	k t ad
1	60	1	0.1	13,155	0	**100**	13155
2	120	2	0.3	1,771	2	**98**	1736
3	180	3	0.4	997	4	**94**	937
4	240	4	0.5	657	6	**88**	579
5	300	5	0.6	490	8	**80**	392
6	360	6	0.8	390	10	**70**	273
7	420	7	0.9	322	12	**58**	187
8	480	8	1.0	273	14	**44**	120
9	540	9	1.1	237	16	**28**	66
10	600	10	1.3	202	18	**10**	20
11	720	12	1.5	324	10	**0**	0
12	840	14	1.8	258	0	**0**	0
13	960	16	2.0	206	0	**0**	0
14	1,080	18	2.3	169	0	**0**	0
15	1,200	20	2.5	143	0	**0**	0
16	1,440	24	3.0	229	0	**0**	0
17	1,800	30	3.8	245	0	**0**	0
18	2,160	36	4.5	169	0	**0**	0
19	2,880	48	6.0	208	0	**0**	0
20	> 2,880	> 48	> 6	332	0	**0**	0
				20776			**17465**

ANNEX 6: NAMES AND DESCRIPTION OF MAIN MAPS

Raster maps of WISDOM analysis are projected at M UTM Central zone 84D with Datum Everest 1830 (single projection for whole country), with cell size/resolution of 100 m, unless otherwise specified.

Module/filename	Type	Description
		Cartographic base
Nepal_VDC_MUTM84	v	Administrative (VDCs/Municipalities) map of Nepal.
Districts_VDC	v	District map of Nepal derived from VDC map.
Dev_reg_VDC	v	Development regions map of Nepal derived from VDC map (most detailed).
physiography_MRV_Db	v	Physiographic Regions of Nepal (source: ICIMOD, Physiographic division of country into Terai, Siwalik, Hill, Middle Mountain and High Mountain)
d_reg_physio	r	Combination of Development regions and Physiographic Regions
geo_region_MRV_Db	v	Classification of districts into three broad geographical regions namely terai, hill and mountain. (Used for Nepal Living Standard Survey-2011 stratifications by CBS) (source: ICIMOD)
vdc_mutm	r	Administrative (VDCs/Municipalities) map of Nepal . Map values correspond to the OBJECTID of map **Nepal_VDC_MUTM84.shp**
vdc_num	r	Administrative (VDCs/Municipalities) map of Nepal. Map values correspond to the vdc_num field of map **Nepal_VDC_MUTM84.shp** The relation with CBS admin codes are mentioned in **vdc_pop11_&_HH_demand.xls**
mutm_msk	r	Mask of analysis based on vdc_mutm (value 1)
mutm_msk0	r	Mask of analysis based on vdc_mutm (value 0)
		Accessibility
		Physical accessibility
road_MRV_Db	v	Road network map of Nepal (Source: ICIMOD)
Road_2013	v	Detailed road network map of Sindhupalchowk district. Example of currently updated road network produced by DOLIDAR.
		Slope
aster30_mutm	r30	Digital Elevation Model of 30m spatial resolution (source: ASTER)
slope30_100	r	Percentage rise slope map of Nepal of 100m spatial resolution based on ASTER DEM of 30m spatial resolution i.e. (**aster30_mutm**) Original ASTER DEM data contains small data errors(sinks) mainly in central himalaya regions.
aster100	r	DTM 100m based on Aster30 (extended outside borders) Aster 30 m focalmean 3 rect. & resampled 100m & extended to allow slope mapping and data filling along borders sink problems!!
aster100_rep		ASTER Digital Elevation Model of 100m based on Aster30 is extended for outside borders and processed accordingly (Aster 30 m focalmean 3 rect. & resampled 100m & extended) to allow slope mapping and data filling along borders. Since original ASTER DEM data contains small data errors (sinks) mainly in central Himalaya regions, they were processed to make depressionless DEMs. The map was repaired for sink problems by mosaicing the affected area with filled patch.
elev_fact2		**Elevation factor** Elevation factor map produced on the basis of following equation: Con("%aster100_rep%" > 2000,1 / (Power(0.132, 0.00048 * "%aster100_rep%") * 7),1)
slprep100_100		Percentage rise slope map of 100m spatial resolution based on Digital Elevation Model of 100m with values extended beyond borders. slope_rd = slope (aster100_rep) and clipping of slope_rd on mutm_msk.
		Slope factor 5^(2 * ("slope100_100" / 100))
slope_fact2		= Power(5,2 * ("%slprep100_100%" / 100)) This operation introduced some NoData cells.
Trans_ln_ed lted	v	Map produced by mosaicing of different topographic maps for transportation features. Transportation categories are defined into 6 catogories in "gridval" attribute. Priority for rasterization was given according to "priority" field.

roads_topo2 r

Rasterzation of Trans_ln_edited on field "gridval" attribute. Priority for rasterization was given according to "priority" field thus obtaining final transportation categories as:

gridval	min/km	Description
1	2	Metalled motorable road
2	4	Secondary motorable road
3	6	Cart track
4	10	Main trail
5	12	Footpath
6	4	Railway
7		Ropeway (not operational)

Cart track and Main trail of older database seems mostly motarable now. This inference is drawn by comparing current DTMP (District Transport Master Plan) database of motorable roads of various districts including Sindhupalchowk prepared by (DOLIDAR) with trans_ln_edited.

Target locations:
Urban areas and dense rural settlements

built_8mn — Builtup area 8 min/km assumed speed for round trip.

pop178_16mn — Dense rural areas with population density (Per SQ KM) > 178. National average density = 177.6 (Per SQ KM)
16 min/km assumed speed for round trip.
= "pop_f3mean" > 178

road4_mnts

code	min/km return trip
1	4
2	8
3	12
4	20

target — Mosaic of built_8mn; pop178_16mn; road4_mnts and clipped on mutm_msk
with min/km values.

target0 — Mosaic of built_8mn; pop178_16mn; road4_mnts and clipped on on mutm_msk
with 0 value.

Friction

frict_min_km — Friction values are calculated in **new_lc_icimod_traveltime_factors.xls**
Friction values estimated by combination of new_lcover and gridcode and transferred to **nlc_gridcode** raster map through reclass using:
recl_nlc_gridcode_frict_mkm.txt

frictminkmex — Friction minutes per kilometer map (frict_min_km) expanded to fill the gaps.

frict_minkm — Friction of land cover classes in minutes per km considering round trip (unloaded and loaded).
Map frictminkmex clipped on mutm_msk to fill in data gaps.

fric_lc_slp — The map is prepared on the basis of following equation.
= frict_minkm * slope_fact2

road2_frict — Map having friction values along road categories including footpaths.
Friction values are assigned from spreadsheet document named **new_lc_icimod_traveltime_factors.xls** through reclassify.

rd2_frict_fl — Map having float version of road friction (road2_frict).
= float(road2_frict)

fric_lcslp_rd — Map produced by mosaicing road friction with friction landcover slope map

= mosaic (rd2_frict_fl ; fric_lc_slp)

cross_mkm (float) — Friction map showing crossing time as minutes per kilometer
Float("fric_lcslp_rd " * "elev_fact2")

cross_m_m (float) — Friction map showing crossing time as minutes per meter
= cross_mkm / 1000

Cost distance

cd2_min_path — **cost distance (target0 ; cross_m_m)**

cd2_hr_i — Cost distance integer map in hours produced by following equation.
= int(cd2_min_path / 60 + 0.5)

		This inserts some NoData values due to large digit numbers.
cd2_20		Map produced by segmentation of cd2_hr_i into 20 classes **(see file new_lc_icimod_traveltime_factors.xls)** All of NoData cells present in central himalaya regions are reclassified to 20 by observing values of neighbourhood cells.
ph_acc01		Map of physical accessibility as percent value. Reclassification of cd2_20 described according to **new_lc_icimod_traveltime_factors.xls** spreadsheet document.

Legal accessibility

Nat_parks_MRV_Db	v	Map of protected areas of Nepal. (source: DNPWC) This map is more detailed than the WCMC-IUCN dataset. To be preferred to the latter for accessibility analysis.
legacc_loc legacc_com		Legal access map is produced with following criteria: **For Local Use:** 0% - Core area of National Parks 30% - Core area of Wildlife Reserves 40% - Core area of Hunting Reserves 50% - Core area of Conservation Areas 80% - Buffer zones of National Parks, Wildlife Reserves and Conservation Areas. **For Commercial Use:** 0% - All protected areas (including buffer zones). Maps are expanded and finally clipped with national border mask to overcome void areas inside.

Demand Module

Population mapping

builtbuf50	Settlements polygons expanded through buffer of 50m in order to be represented in raster format and rasterized to 100 m
blt_buf_1_0	= mosaic(built_buf50; mutm_msk0)
	Procedure of pop mapping using builtup, buildings and trails
builtup1000	= builtbuf50 * 1000
Settlements_points_in_84	Settlements points mosaiced into single layers
buildings	Rasterized map of Settlements_points_in_84.shp (value: 1 to 32 : number of settlement points per pixel)
pz_builtup2	Population Zone "builtup" based on Icimod land cover and other settlement polygon data (value 1; 0)
pz_building2	Population Zone "buildings" of prepared settlement point data (values 1 to 32)
pz_rd2 pz_rd2_farm	Population Zone "roads" with (value 1) with addition of farmland for the VDC not covered by roads and building data
	See **vdc_pop11_&_demand_sector_2.xls**
mul_builtup2	recl_vdc_num_mul_pz_builtup2.txt
mul_building2	recl_vdc_num_mul_pz_building2.txt
mul_rd2_farm	recl_vdc_num_mul_pz_rd2_farm.txt
pop_builtup2	Population of builtup area (*100) = "mul_builtup2" * "pz_builtup2"
pop_building2	Population of building area (*100) = "mul_building2" * "pz_building2"
pop_rd2_farm	Population of roadside (and farm in gap areas) (*100) = "mul_rd2_farm" * "pz_rd2_farm"
pop2011x100	Persons per pixel (*100) matching Census 2011 VDC data. See details in **vdc_pop11_&_demand_sector_2.xls** = "pop_rd2_farm" + "pop_building2" + "pop_builtup2"

Consumption mapping

pccons_adkg_3	Per capita fuelwood consumption (considering total population, i.e. users and non users) including HH, industrial, commercial sectors, cremation wood and construction material. Data reference: **vdc_pop11_&_demand_sector_2.xls**

		Equation: reclass(vdc_num; recl_vdc_num_pccons_adkg_3.txt) No public sector consumption included.
cons_adkg_3		Fuelwood consumption air dry per pixel in kilogram (ad kg per pixel) including household, industrial and commercial sectors, cremation wood and construction material given by following equation: **Int("pop2011x100" * "pccons_adkg_3" / 100 + 0.5)**
		Revision of rural consumption in deficit areas of Terai. A distinction is made between the rural use of "conventional" fuelwood (solid wood pieces from stems and branches) and of "marginal" fuelwood (twigs produced through annual/ periodic pruning of trees and shrubs on farmlands). In rural areas of Terai where conventional fuelwood is not available (here considering an horizon of 6 km) the "marginal" fuelwood is assumed to replace conventional fuelwood (here considered to replace 50%). In hills and mountain regions the rural deficit areas are small and "conventional" fuelwood resources are never too far.
rural_msk		Map of mask of rural areas (val 1) recl_vdc_num_rur_msk.txt
rural_cons		Map of rural consumption only = "cons_adkg_3" * "rural_msk"
rurcons_f60		Map of rural consumption for the analysis of fulfilled percentage in rural areas produced with following parameters: =focalmean (rural_cons, circle, 60, mean)
pc_rurfulf6km		Percentage of rural consumption fulfilled within 6 km derived from following parameters: = Con("rurcons_f60" == 0, 0, Int("av1mai_f60" / "rurcons_f60" * 100 + 0.5))
cons_revrur		"Conventional" Fuelwood consumption (ad kg per pixel) including Household, industrial and commercial sectors, cremation wood and construction material Revised for rural Terai in consideration of probable use of "marginal" fuelwood (twigs and annual pruning of farm trees and shrubs) to fill 1/2 of the gap estimated within a 6km horizon derived as: Con("terai_rur_msk" == 0,"cons_adkg_3",Con("pc_rurfulf6km" > 80,"cons_adkg_3", "cons_adkg_3" - "cons_adkg_3" * (100 - "pc_rurfulf6km") / 200))
		Supply Module
		Land cover
Biomass_study.mdb	v	Database containing BIOMASS_BASE (and relevant LUTs and queries) based on the land cover dataset produced by Marzoli as integration of available land cover data. Note: this map has many geometry errors and cannot be converted to raster.
biomass_base_mutm_repaired	v	Biomass base map projected to MUTM Central zone 84 with repaired geometry. The repair was done by dividing the map into various subsets that were eventually merged.
lc_biom_01.mdb		Geodatabase **lc_biom_01** (= biomass_base_mutm_repaired.shp) gdb contents: **BIOMASS_BASE** fields: BIOMASS_T_HA (agb estimated by Walter based on inventory data and expansion factors) (ad t / ha) DE_BIOM_T_HA (Dendroenergy biomass based on BIOMASS_T_HA removing leaves, twigs and stumps (ad t / ha) = [biomass_t_ha]*(1-0.15-0.039) [15% leaves and smaller twigs; 3.9% stump] DEB_kgha (ad kg / ha) = int(DE_BIOM_T_HA * 1000 +0.5) MAI_DEB_percent (MAI of Dendroenergy biomass based on tropical and sub-tropical stock-MAI values (ad t / ha) = ([de_biom_t_ha]^-0.5069)*22.683 for coniferous forests = ([de_biom_t_ha]^-0.5879)*37.058 for all other formations MAI_DEB_kgha (ad kg / ha) = Int(([de_biom_t_ha]*[mai_deb_percent]/100)*1000+0.5)
		Stock and MAI
agbadtha_1	r	Aboveground air dry biomass in ton per hector (ad t / ha) Raster of BIOMASS_BASE on field BIOMASS_T_HA.
agb_adkg_1	r	Aboveground air dry biomass in Kilogram per hectare i.e. (ad kg / ha). NOT CLEANED along borders !!

debadkgha_1 **debadkg** (cleaned) r	Map of dendroenergy airdry biomass in kilogram per hectare. (ad kg / ha) Raster of BIOMASS_BASE on field DEB_kgha Map is expanded to fill in data gaps along borders.
maideadkg_2 r	Mean Annual Increment (MAI) of Dendroenergy biomass (ad kg / ha /yr) Raster of BIOMASS_BASE on field MAI_DEB_kgha (revised values for broadleaves and coniferous) With data gaps along borders
mai_adkg	Map of Mean Annual Increment (MAI) of Dendroenergy biomass (ad kg / ha /yr) which is expanded to fill in data gaps along borders and clipped to mask.
ph1acmai_adkg	Physically accessible Mean Annual Increment (MAI) derived as: Int("mai_adkg" * "ph_acc01" / 100 + 0.5)
ac1mai_adkg	Physically and legally accessible Mean Annual Increment (MAI) for <u>local consumption</u> **= Int("ph1acmai_adkg" * "legac_loc" / 100 + 0.5)**
	Calculation of accessible MAI (ac1mai) by district. zst_Districts_VDC_ac1mai_adkg.dbf
mul_indrndwd	Multiplier (by District) to be applied to the accessible Mean Annual Increment (MAI) to deduct the industrial roundwood and obtain the available MAI Data reference in spreadsheet named **Timber Sale by District_2010_11_RD.xls** Multiplier map created through reclass of district map: recl_district_mul_indrndw_factor.txt
av1mai	**Availabe (and accessible)** Mean Annual Increment (**MAI) calculated as:** **= Int("ac1mai_adkg" * "mul_indrndwd" / 1000 + 0.5)**
av1mai_f60	Map produced for the analysis of percentage fulfilled in rural areas given by the relation: =focalmean (av1mai, circle, 60, mean)
	Integration Module
	Cell-level balance
bal_1	Cell-level balance map calculated by the following relation: = "av1mai" - "cons_adkg_3"
bal_2	**Cell-level balance map considering revised demand as:** **= "av1mai" - " cons_revrur "**
	Local-level balance
loc_bal_3km	**Local balance map assuming a harvesting horizon of 3km radius.** = focalmean(bal1; 20 + 10; circle; mean) and clipped on mutm_msk
loc_bal2_3km	**Local balance map assuming a harvesting horizon of 3km radius considering revised demand** = focalmean(bal_2; 20 + 10; circle; mean) and clipped on mutm_msk
	Commercial balance
	GACC: Local-level commercial balance based on 500 ad kg/ha/yr (410 od) surplus threshold, stock > 14.66 ad t /ha (12 od) and excluding entirely the surplus from ALL Protected Areas and Buffer Zones.
	Model for Commercial balance: 1: Combal_tmp1 = Con("**loc_bal2_3km** " < 500, Con("**loc_bal2_3km** " >=0,0, " **loc_bal2_3km** "), " **loc_bal2_3km** ") 2: Combal_tmp2 = Con("Combal_tmp1">0, Con("debadkg" > 14660, "Combal_tmp1",0), "Combal_tmp1") 3: Combal = Con("Combal_tmp2">0, Con("legac_com " == 0,0," Combal_tmp2")," Combal_tmp2")
	Local deficit and peak deficit locations
Pnts_20kmdefisum.shp	Peak deficit locations Create point map placing points on peak deficit locations (based on 20km deficit map) Assign deficit value to the points from defisum20km and define PointID code
loc_def2_3km	**Local deficit within 3 km radius given by the condition as:** = Con("**loc_bal2_3km** " <= 0," **loc_bal2_3km** ",0)
defi2sum20km	Major deficit areas SUMMARIZING the deficit within a 20 km radius. =focalSUM ("**loc_def2_3km"**, circle, 200)
Pnts_20kmdefisum.shp	Point map marking peak deficit locations based on 20 KM deficit map with assigned deficit value from defisum20km and defined PointID code.

Woodshed analysis based on Dinamica EGO

	Nepal - woodshed_Nep_01.egoml
cross_m_m.tif	Friction map (cross_m_m) exported in tiff format for the input of Dinamica model.
Pnts_20kmdefisum.shp	Points with cumulative deficit in Nepal estimated on a 20 km radius (focalSUM) extracted from defisum20km that represent the deficit of major consumption cities to be used as point values in IDW Dinamica analysis.
pnt_id.tif	Categorical map with ID of major deficit points matching map extent to that of cross_m_m.tif and introducing following parameters in point to raster tool. = Pnts_20kmdefisum.shp; pnt_ID; MOST_FREQUENT; NONE; snap to cross_m_m.tif
id_deficit_nep2.csv	**Lookup Table** With ID points values and deficit values (positive)
	Outputs of program **woodshed_Nep_01.egoml :**
cost##.tif	Maps produced by interpolation of individual points. (temporary, saved on disk)
sumcost##.tif	Progressively cumulative maps of individual points interpolation. (temporary, saved on disk) Last map= sumcost27.tif
wcd_prec2.tif	**woodshed_Nep_prec2.egoml** **wcd_Nep2_prec2.egoml** Precision 2 (2 iterations) **Final cumulative map of all individual points interpolation maps (weighted cost distance)** cost##.tif : Individual point interpolation map (temporary, not saved on disk) sumcost##.tif : Progressively cumulative maps of individual points interpolation maps (temporary, saved on disk in folder **Woodshed\wcd2**) . Last map= sumcost27.tif
wcd_prec2grd	grid format of **wcd_prec2.tif**
wcd_prec2f1	focalmean (circle, 1) to fill the NoData at point position
wcd02_tmp	mosaic of **wcd_prec2grd** and **wcd_prec2f1 (last)**
wcd02	**Weighted cost distance map** = wcd02_tmp * mutm_msk
wcd02_250	**recl_nep_wcd2_250_cl_06.txt**
wcd02_250w	Weight to be used to distribute pressure on surplus resources = 251 - "wcd02_250"
	Travel time from major deficit points
time_wcd2_pnt	Transport time (going and back) from major deficit points of wcd02 woodshed. Values in minutes given by: cost distance (pnts_val2; cross_m_m)
wcd2_hours	Transport time (going and back) from major deficit points of wcd02 woodshed. Values in hours given by: Reclass(time_wcd2_pnt using symbology)
ws209_8hr	Mask of woodshed area 209 and 8hrs limit generated as: Con("wcd02_250" < 210, Con("wcd2_hours" <= 8, 1, 0),0)
wsurp_8hr	Creation of the weighted surplus (surplus * pressure level) within the 8-hours zone around major deficit points for the distribution of the deficit as harvesting . = Con("wcd2_hours" <= 8,Con("combal" > 0,"combal" * "wcd02_250w",0),0)
wsurp209_8hr	Creation of the weighted surplus value (surplus * pressure level) within the nominal woodshed zone around major deficit points and within 8-hours for the distribution of the deficit as harvesting . = Con("wcd02_250" < 210,Con("wcd2_hours" <= 8,Con("combal" > 0,"combal" * "wcd02_250w",0),0),0)
ws209_12hr	Mask of woodshed area 209 and 12hrs limit Con("wcd02_250" < 210, Con("wcd2_hours" <= 12, 1, 0),0)
def_w209_12hr	Deficit map in ws209 and within 12 hours from major deficit points Con("ws209_12hr" == 1,Con("combal" < 0,"combal",0),0)

	tot deficit (ad kg)**: 3,278,631,957**
wsur209_12hr	Creation of the weighted surplus value (surplus * pressure level) within the nominal woodshed zone around major deficit points and within 12-hours for the distribution of the deficit as harvesting . =Con("**ws209_12hr** " == 1, Con("combal" > 0,"combal" * "wcd02_250w",0),0) total weighted surplus : **176,757,702,900**
har_w209_12hr	Harvesting by pixel : 3,278,631,957 / 176,757,702,900 = 0.018548736 "wsur209_12hr" * 0.018548736
harsus209_12h	Harvesting sustainability map Con("har_w209_12hr" > 0,"har_w209_12hr" - "combal") Con("har_w209_12hr" > 0," combal" - "har_w209_12hr")
nrb209_12h	**Non-Renewable harvesting within woodshed209 and within 12 hrs from major deficit sites Unsustainable fuelwood extraction in ad kg. = measure of (forest) degradation**