# 1 THE AGRO-ECOLOGICAL ZONES (AEZ) METHODOLOGY

An agro-ecological zones methodology has been in use since 1978 for determining agricultural production potentials and carrying capacity of the world's land area. An agro-ecological zone, as originally defined, is comprised of all parts of gridcells on a georeferenced map that have uniform soil and climate characteristics. The suitability of each of these zones for rainfed production of various crops, under different input and management scenarios is then evaluated. The yield potential of the crops most suited to each zone where rainfed crop production is possible, determines the overall agricultural production potential of that zone.

Crops evaluated originally include food, fibre and fodder crops and pasture grasses. The Food and Agriculture Organization of the United Nations (FAO), in collaboration with the International Institute for Applied Systems Analysis (IIASA), has updated its agro-ecological zones (AEZ) methodology (FAO & IIASA, 2002). The updated version permits a more refined evaluation of biophysical limitations than the original, and takes into account the production potential of a larger number of crops.

In conjunction with the updating exercise, a worldwide spatial land resources database has been created that contains both primary datasets and derived datasets for a large number of variables that affect the production potential of the world's land area or reflect the choices that people have made about how to use the land.

The AEZ framework incorporates the following basic elements:

- a georeferenced land resources database that contains some 2.2 million gridcells, and includes (i) an environmental conditions component comprised of georeferenced global databases for climate, soils, terrain and elevation, and (ii) a spatial land use and land cover component covering forests, protected areas, irrigated areas, population distribution and density, land required for habitation and infrastructure, estimates of cropland, grazing land and sparsely vegetated or barren land, and farming systems;

- a standardized framework for the characterization of soil, terrain and climatic conditions relevant to agricultural production, and identification of areas with specific climate, soil and terrain constraints to rainfed crop production;

- selected agricultural production systems with defined input and management relationships, and crop-specific environmental requirements and adaptability characteristics; these are termed land utilization types (LUTs);

- procedures for calculating the potential agronomically attainable yield and for matching environmental requirements of individual crops and LUTs with the respective environmental characteristics contained in the land resources database, by land unit and gridcell, thus permitting estimation of crop-specific suitability indices for each gridcell in the database, under different levels of inputs and management conditions;

- quantification of crop and land productivity potential under different cropping pattern and LUT assumptions;

- applications for estimating the land's population-supporting capacity and for multiple-criteria optimization of land resource use for sustainable agricultural development, incorporating socioeconomic and demographic as well as environmental factors.

The AEZ starts with climate and uses terrain and soil types as modifiers, that is climate is determining; only if climate is suitable will the suitability of the terrain and the soil type be considered. The AEZ approach, as updated for this report, distinguishes 171 crop types, each of which is assessed at three generic levels of inputs and management for rainfed conditions and at two generic levels of inputs and management for irrigated conditions, making a total of 855 crop LUTs. A complete description of the methodology and results obtained for regions across the globe can be found in FAO & IIASA, 2002 and 2003.

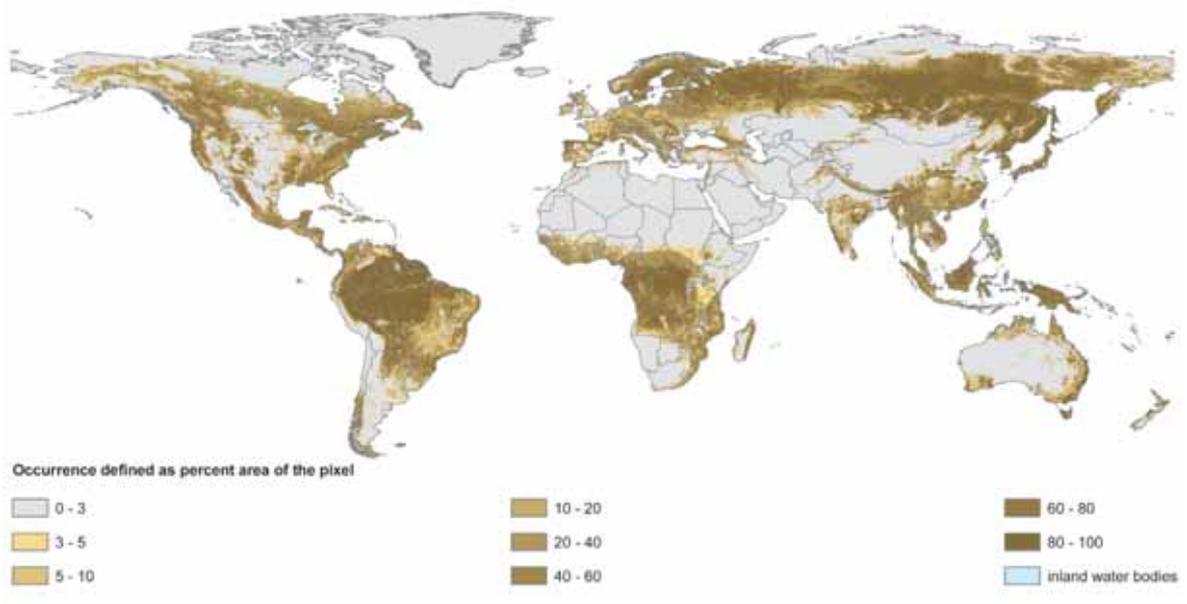# 2 GLOBAL LAND COVER AND AVAILABILITY OF LAND FOR RAINFED AGRICULTURE

This Annex contains five global maps showing the part of the world's land area that is currently used for each of the following purposes: (i) forest, (ii) cropland, (iii) pasture and browse, (iv) barren and sparsely vegetated land and (v) built-up area (including urban area and rural settlements) and artificial surfaces. The underlying map databases have been prepared at a resolution of 5 arc-minutes, or 81 square kilometres at the equator and about half that at +/- 60' latitude. Each map database gives the occurrence of one land cover type in every gridcell of the world's land surface, expressed as a percentage of the gridcell area. The percentage occurrences of the land cover types in each gridcell add up to 100 percent. Additional maps show the occurrence of irrigated area within cropland, and the occurrence of protected area globally. It is s not feasible to generate a single visually meaningful map that combines the occurrence of all five land cover types, except by using a simple classification system. The one shown in the Box A2.1 has been used to generate Map A.2.8 and to estimate the distribution of rural population by land cover type. The GIS databases for all eight maps shown in this Annex are available on the DVDs that contain the FGGD Digital Atlas for the year 2000 (FAO, 2006).
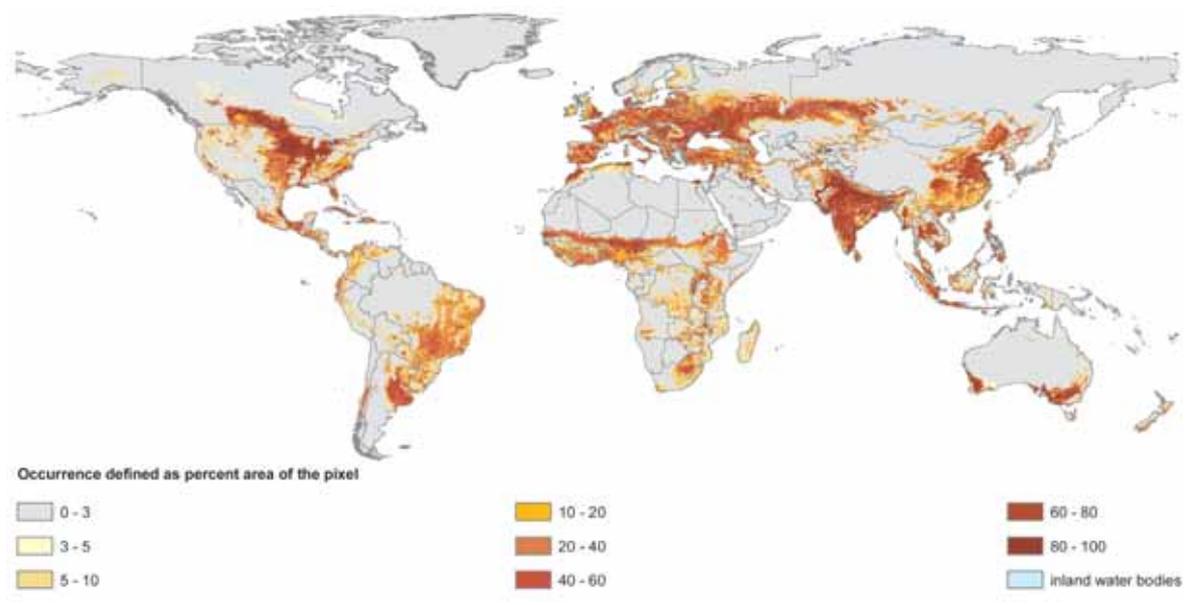
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### BOX A2.1
### DEGREE OF DOMINANCE OF LAND COVER TYPES

- ■ > 50% built-up area and artificial surface
- ■ > 75% forest
- ■ 50-75% forest
- ■ > 75% crops
- ■ 50–75% crops

- ■ > 75% pasture and browse
- ■ 50–75% pasture and browse
- ■ > 75% barren and sparsely vegetated
- ■ 50–75% barren and sparsely vegetated
- ■ mixed (no land cover type dominant)

MAP A2.1

**Occurrence of forest**



Occurrence defined as percent area of the pixel

| | | |
|---|---|---|
| 0 - 3 | 10 - 20 | 60 - 80 |
| 3 - 5 | 20 - 40 | 80 - 100 |
| 5 - 10 | 40 - 60 | inland water bodies |

MAP A2.2

**Occurrence of cropland**



Occurrence defined as percent area of the pixel

| | | |
|---|---|---|
| 0 - 3 | 10 - 20 | 60 - 80 |
| 3 - 5 | 20 - 40 | 80 - 100 |
| 5 - 10 | 40 - 60 | inland water bodies |

MAP A2.3
**Occurrence of pasture and browse**



Occurrence defined as percent area of the pixel

| | | | | |
|---|---|---|---|---|
| 0 - 3 | 10 - 20 | 60 - 80 |
| 3 - 5 | 20 - 40 | 80 - 100 |
| 5 - 10 | 40 - 60 | inland water bodies |
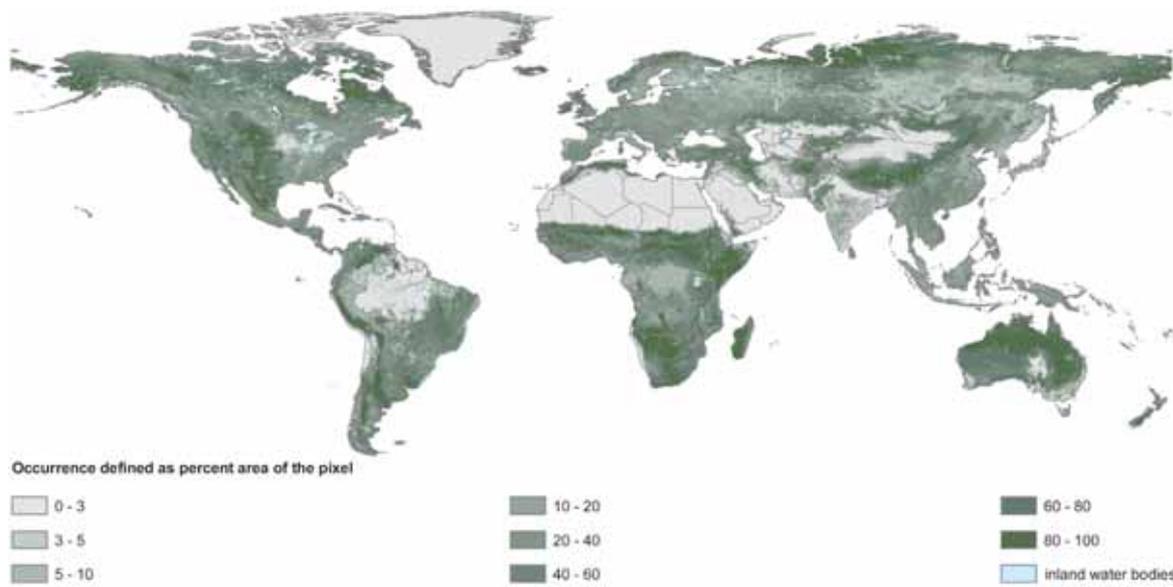
MAP A2.4
**Occurrence of barren and sparsely vegetated land**



Occurrence defined as percent area of the pixel

| | | | | |
|---|---|---|---|---|
| 0 - 3 | 10 - 20 | 60 - 80 |
| 3 - 5 | 20 - 40 | 80 - 100 |
| 5 - 10 | 40 - 60 | inland water bodies |
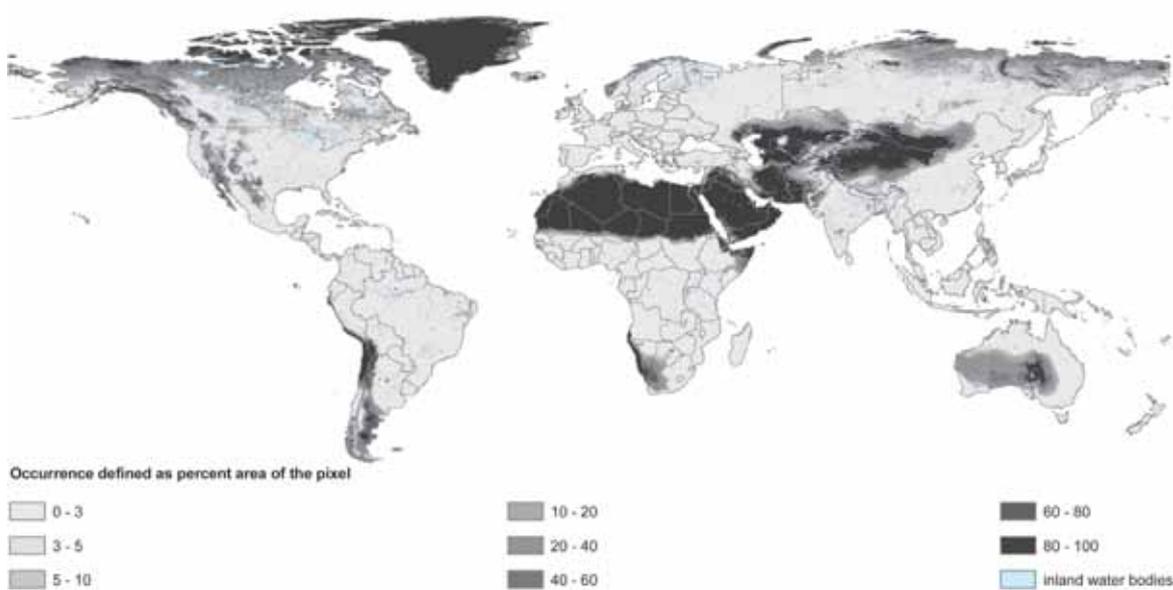
MAP A2.5

**Occurrence of built-up area and artificial surface**



Occurrence defined as percent area of the pixel

| | | | |
|---|---|---|---|
| 0 - 3 | 10 - 20 | 60 - 80 | |
| 3 - 5 | 20 - 40 | 80 - 100 | |
| 5 - 10 | 40 - 60 | inland water bodies | |
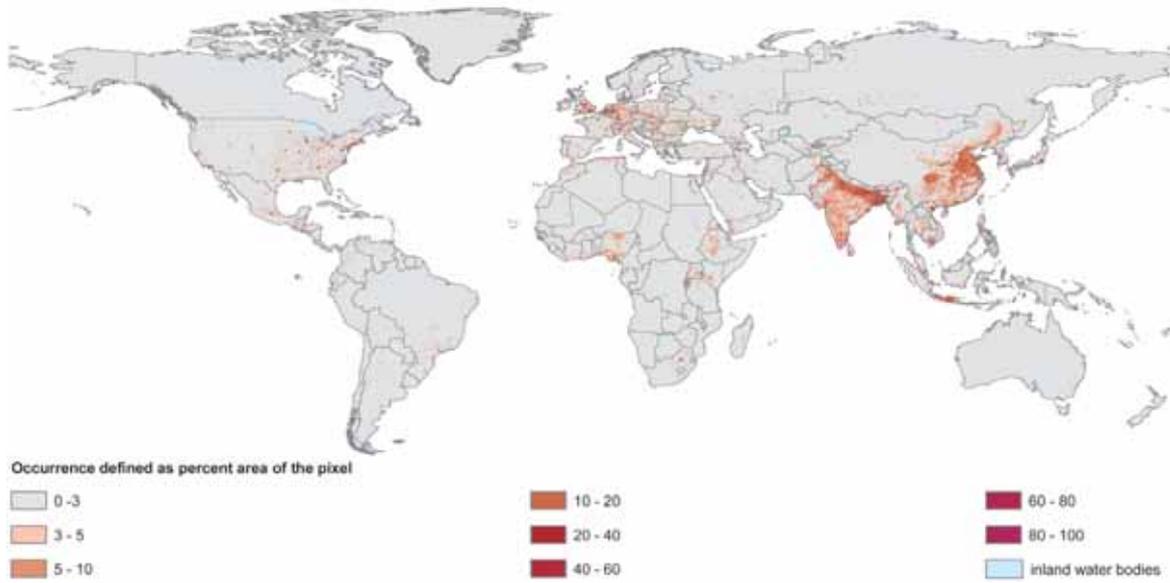
MAP A2.6

**Occurrence of irrigated area**



Occurrence defined as percent area of the pixel

| | | |
|---|---|---|
| 0 | 5 - 10 | 50 - 75 |
| < 0.1 | 10 - 20 | 75 - 100 |
| 0.1 - 1 | 20 - 35 | |
| 1 - 5 | 35 - 50 | |

MAP A2.7

**Protected area**



**Protected areas**

- Protected areas where agriculture is likely
- Protected areas where agriculture is not likely
- Non-protected areas
- Inland water bodies
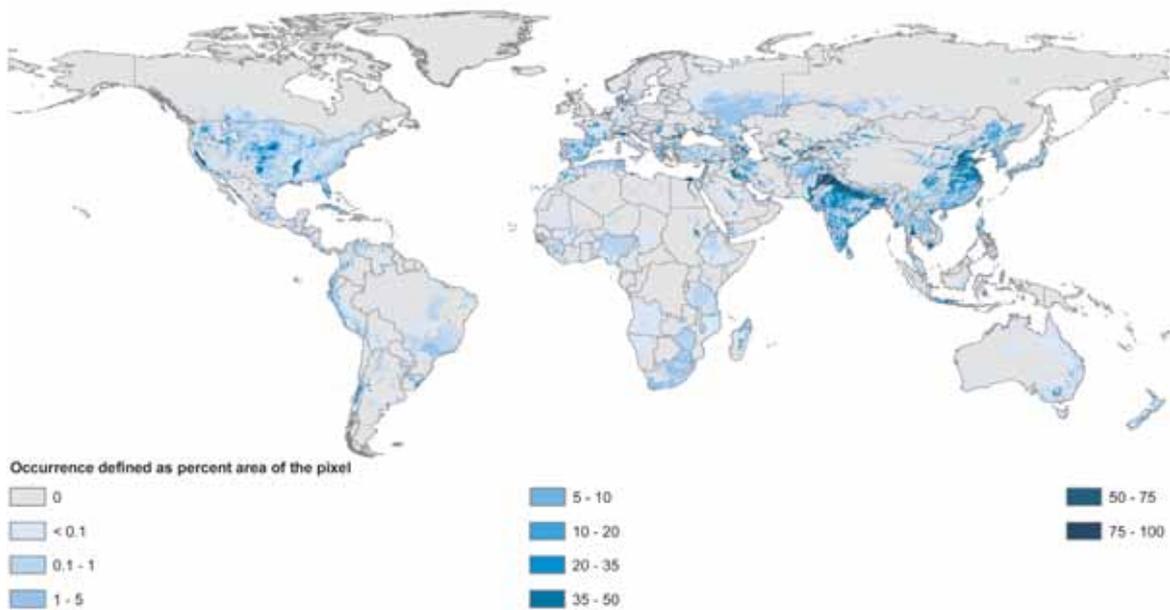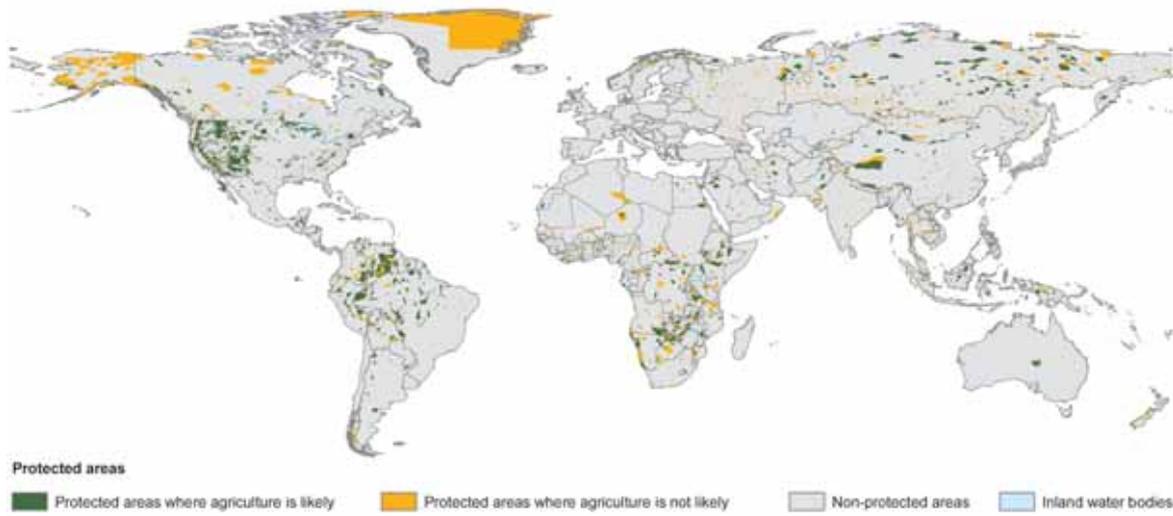
MAP A2.8

**Global land cover distribution, by dominant land cover type**



**Combined land cover classes**

- > 75% crops
- 50 - 75% crops
- > 50% artificial surface
- > 75% forest
- 50 - 75% forest
- mixed
- > 75% pasture and browse
- 50 - 75% pasture and browse
- inland water bodies
- > 75% barren and sparsely vegetated
- 50 - 75% barren and sparsely vegetated
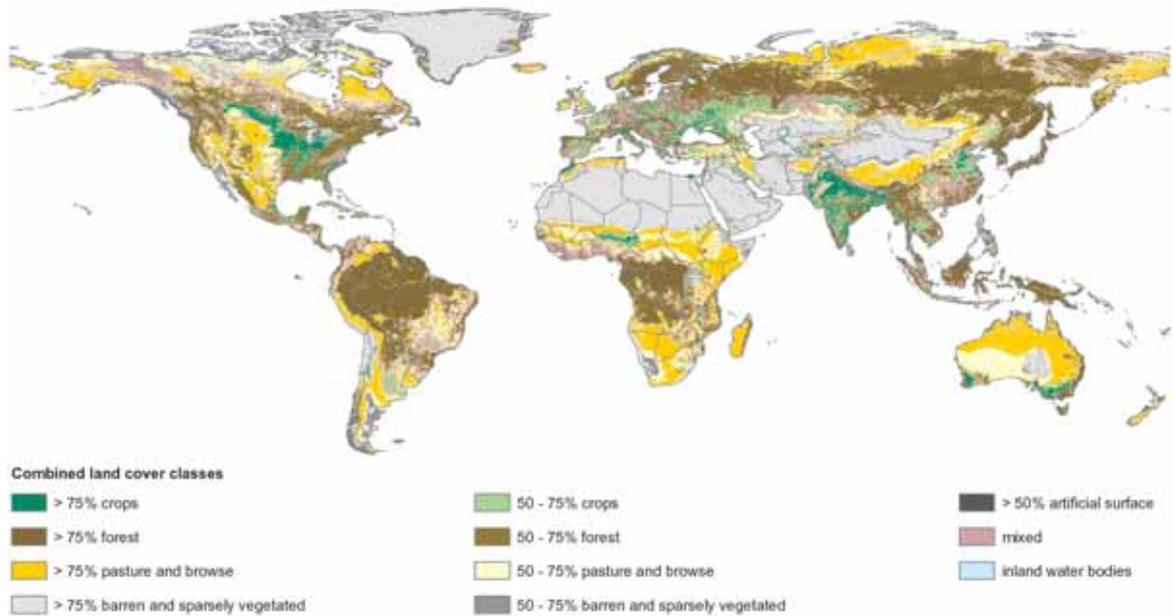
## A2.1 METHOD USED TO ESTIMATE THE DISTRIBUTION OF GLOBAL LAND COVER

The land cover databases are based on the GAEZ study (FAO & IIASA, 2002); for this report, they have been updated and refined, following the method described below.

The primary objective of the work was to determine the land area actually in use for rainfed crop cultivation and pasture at the time of the study. For this purpose the GAEZ assessment first created the land cover databases for built-up area, barren and sparsely vegetated land, forest cover, protected area with and without agriculture and irrigated area, and excluded these from its estimation of land currently used for rainfed crops and pasture. The remaining area was allocated to cropland or pasture and browse according to its suitability characteristics.

For the estimation of land cover shares in individual 5 arc-minute gridcells, data from several land cover datasets have been used, namely:

i. the GLC2000 land cover regional and global classifications (European Commission – Joint Research Centre. 2003);

ii. the global land cover categorization, compiled by IFPRI (IFPRI, 2002), based on a reinterpretation of the *Global Land Cover Characteristics Database* (GLCC) version 2.0 (EDC, 2000);

iii. the *Global Forest Resources Assessment* of FAO (FAO, 2001);

iv. a refinement of the global 5 arc-minute inventories of irrigated land (FAO & University of Kassel, 2002);

v. an interpretation of the IUCN-WCMC protected areas inventory at 5 arc-minutes (along with other convention types of legally protected areas to distinguish protected land in two categories, namely areas where some restricted agricultural use is permitted from areas where cultivation is strictly prohibited) (UNEP-WCMC Online);

vi. a 30 arc-second population density inventory for year 2000 which provided the basis for estimating land required for housing and infrastructure (population density map developed by FAO/SDRN, based on spatial data of LandScan 2002, with calibration to UN 2000 population figures) (FAO, 2005).

Land cover interpretation schemes have been devised that allow a quantification of each 30-arc-second gridcell into seven main land use/land cover shares. These shares are: cultivated land, subdivided into (i) rainfed land and (ii) irrigated land, (iii) forest, (iv) pasture and other vegetation, (v) barren and very sparsely vegetated land, (vi) water and (vii) urban land and land required for housing and infrastructure.

An iterative calculation procedure has been implemented to estimate consistent land cover class weights that allow the quantification of major land use/land cover shares in individual 5 arc-minute gridcells. Starting values of class weights used in the iterative procedure were obtained by cross-country regression of statistical data of cultivated and forest land against aggregated national land cover class distributions obtained from the geospatial analysis.

## A2.2 METHOD USED TO ESTIMATE LAND CURRENTLY AVAILABLE FOR RAINFED AGRICULTURE

The suitability of all global land area for rainfed cultivation of nine individual crop types and pasture grasses has been evaluated by the study team (see Section 4.2 ), and individual suitability maps that contain the results for nine crop groups and pasture are included in the DVDs that accompany the FGGD Digital Atlas for the year 2000 (FAO, 2006). However, this report gives results only for land cover classes not already in use for human settlements, forests or irrigated agriculture.

In order to determine the land area currently available for rainfed crop cultivation and pasture in year 2000, irrespective of suitability, the following land cover classes were considered to be not currently available: urban area, closed forest, protected area where agriculture should not be occurring and irrigated area. From FAO's 5 arc-minute urban area grid, all pixels where urban area exceeds 25 percent of the area have been excluded from estimation of currently available land. From the land cover grids, all pixels where forest cover exceeds 75 percent of the area, all pixels classified by WCMC as pixels where agriculture should not be occurring and all pixels where irrigated area exceeds 50 percent have been excluded. The suitability of the remaining area for rainfed agriculture  and the distribution of rural population in this area are reported here. Table A.2.1 shows the distribution of total rural population by region and dominant land cover type for rural area considered to be not currently available for rainfed agriculture and for rural area considered to be currently available for rainfed agriculture, irrespective of suitability.

TABLE A2.1

**Distribution of rural population, by region and dominant land cover type**

| Major area and region | Rural population in pixels not considered to be currently available for rainfed agriculture | | | | | Rural population in pixels considered to be currently available for rainfed agriculture | | | | | | Rural population Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Urban area >25% | Forest >75% | Protected area where agriculture should not be occurring | Irrigated area >50% | Sub-total | Forest 50-75% | Crops 50% or more | Pasture and browse 50% or more | Barren and sparsely vegetated 50% or more (dominant) | Mixed (no land use dominant) | Sub-total | Total |
| | persons (1 000) | persons (1 000) | persons (1 000) | persons (1 000) | persons (1 000) | persons (1 000) | persons (1 000) | persons (1 000) | persons (1 000) | persons (1 000) | persons (1 000) | persons (1 000) |
| **AFRICA** | | | | | | | | | | | | |
| Eastern Africa | 2,425 | 2,914 | 5,753 | 106 | 11,198 | 19,230 | 18,497 | 101,654 | 3,450 | 38,631 | 181,462 | 192,660 |
| Middle Africa | 395 | 16,486 | 1,998 | - | 18,879 | 15,570 | 2,760 | 15,771 | 354 | 10,480 | 44,935 | 63,814 |
| Northern Africa | 4,596 | 261 | 264 | 32,371 | 37,492 | 1,288 | 8,661 | 26,028 | 8,066 | 5,585 | 49,628 | 87,120 |
| Southern Africa | 817 | 12 | 564 | - | 1,393 | 383 | 492 | 19,013 | 258 | 2,205 | 22,351 | 23,744 |
| Western Africa | 3,772 | 1,728 | 1,931 | 34 | 7,465 | 4,941 | 30,341 | 51,812 | 1,538 | 41,204 | 129,836 | 137,301 |
| **AMERICAS** | | | | | | | | | | | | |
| Caribbean | 933 | 9 | 96 | 199 | 1,237 | 345 | 2,307 | 3,553 | 156 | 5,184 | 11,545 | 12,782 |
| Central America | 1,904 | 183 | 505 | 1,425 | 4,017 | 8,312 | 6,592 | 9,466 | 442 | 14,729 | 39,541 | 43,558 |
| Northern America | 6,081 | 729 | 315 | 316 | 7,441 | 22,612 | 18,883 | 5,529 | 801 | 13,476 | 61,301 | 68,742 |
| South America | 6,196 | 8,863 | 1,118 | 369 | 16,546 | 14,223 | 2,959 | 34,073 | 2,495 | 23,509 | 77,259 | 93,805 |
| **ASIA** | | | | | | | | | | | | |
| Eastern Asia | 57,433 | 15,470 | 4,918 | 82,627 | 160,448 | 48,348 | 258,838 | 96,361 | 9,751 | 256,859 | 670,157 | 830,605 |
| Japan | 3,842 | 4,822 | 262 | 4,150 | 13,076 | 5,575 | - | 250 | 492 | 8,166 | 14,483 | 27,559 |
| South-central Asia | 43,111 | 10,639 | 14,081 | 228,528 | 296,359 | 39,151 | 521,040 | 31,806 | 27,459 | 124,770 | 744,226 | 1,040,585 |
| South-eastern Asia | 19,086 | 5,593 | 4,478 | 10,229 | 39,386 | 20,772 | 121,882 | 14,511 | 3,022 | 120,937 | 281,124 | 320,510 |
| Western Asia | 3,178 | 585 | 178 | 6,957 | 10,898 | 1,718 | 8,152 | 22,286 | 11,371 | 9,723 | 53,250 | 64,148 |
| **EUROPA** | | | | | | | | | | | | |
| Eastern Europe | 5,318 | 7,026 | 1,946 | 2,313 | 16,603 | 9,401 | 45,717 | 2,999 | 343 | 19,909 | 78,369 | 94,972 |
| Northern Europe | 2,141 | 1,169 | 84 | - | 3,394 | 1,855 | 3,457 | 4,711 | 161 | 2,585 | 12,769 | 16,163 |
| Southern Europe | 2,993 | 3,649 | 125 | 3,922 | 10,689 | 5,259 | 16,327 | 3,482 | 390 | 13,107 | 38,565 | 49,254 |
| Western Europe | 5,252 | 1,285 | 36 | 284 | 6,857 | 3,267 | 7,766 | 3,655 | 63 | 8,879 | 23,630 | 30,487 |
| **OCEANIA** | | | | | | | | | | | | |
| Australia and New Zealand | 223 | 365 | 36 | 20 | 644 | 367 | 1,197 | 1,519 | 57 | 384 | 3,524 | 4,168 |
| Melanesia | 44 | 897 | - | - | 941 | 1,926 | - | 592 | 86 | 1,031 | 3,635 | 4,576 |
| **Developed** | 25,850 | 19,045 | 2,804 | 11,005 | 58,704 | 48,336 | 93,347 | 22,145 | 2,307 | 66,506 | 232,641 | 291,345 |
| **Developing** | 143,890 | 63,640 | 35,884 | 362,845 | 606,259 | 176,207 | 982,521 | 426,926 | 68,448 | 654,847 | 2,308,949 | 2,915,208 |
| **World** | 169,740 | 82,685 | 38,688 | 373,850 | 664,963 | 224,543 | 1,075,868 | 449,071 | 70,755 | 721,353 | 2,541,590 | 3,206,553 |