Farming the Planet. 2: The Geographic Distribution of Crop Areas and Yields in the Year 2000

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Abstract

Croplands cover ~15 million km^2 of the planet and provide the bulk of the food and fiber essential to human well-being. Most global land-cover datasets from satellites group croplands into just a few categories, thereby excluding information that is critical for answering key questions ranging from biodiversity conservation to food security to biogeochemical cycling. Information about agricultural land-use practices like crop selection, yield, and fertilizer use is even more limited. Here we present land-use datasets created by combining national-, state-, and county-level census statistics with a recently updated global dataset of croplands on a 5 minute by 5 minute (~10 km by 10 km) latitude-longitude grid. The resulting land-use datasets depict circa the year 2000 the area (harvested) and yield of 175 distinct crops of the world

1. Introduction

Human land uses practices, especially those tied to agriculture, have transformed the biosphere (Vitousek et al., 1997; Foley et al., 2005). The ~40% of terrestrial photosynthesis appropriated for human use (Vitousek et al., 1986; Rojstaczer et al., 2001), the ~50% of the global nitrogen flux from synthetic fertilizers and fossil fuels combustion (Matson et al., 1997; Vitousek et al., 1997), and the freshwater withdrawals that exceed ~50% of the accessible supply (Postel et al., 1996), lead to the same conclusion—never has a single species had such a planetary presence. Although we know much about the *magnitude* of the human transformation to the biosphere, we know little about its exact *location and geographic manifestation*. Improved spatial understanding of global change requires much better descriptions of agricultural land cover and land use than are currently available.

Agriculture is a major component of global environmental change. Humans have transformed ~15 million km^2 of natural vegetation into cropland and another ~31.5 million km^2 into pasture (Ramankutty, submitted as companion paper). The impacts of agriculture, however, extend far beyond changes in land cover to virtually all facets of the biosphere. Global changes in terrestrial carbon storage and methane emissions result largely from agriculture (Aselmann and Crutzen, 1989; Duxbury, 1994; Houghton, 1995), which contributes one-quarter of anthropogenic carbon emissions (Houghton, 2003) and one-fifth of the annual increase in radiative forcing from carbon dioxide, nitrous oxide, and methane (Cole et al., 1997). The environmental consequences of agriculture, however, permeate more than just the carbon cycle and climate (Foley et al., 2005). Local ecosystem services like water filtration, soil formation, disease regulation, and flood control are being radically altered as well. Therefore, attempts to understand and address the environmental impacts of agriculture cannot stop with generic land-cover categories like ‘cropland’. What grows and how it grows matter.

Unfortunately, the current generation of remote sensing datasets and global models only account for the *extent* of agricultural land cover (usually in one or two categories like ‘cropland’ or ‘cropland / vegetation mosaic’) and entirely overlook the actual *practice* of agriculture (what is grown, how it is grown, what inputs are used). While satellites can help detect agricultural land cover, they are ill suited for identifying land use. New datasets, however, are beginning to describe land-use practices like crop selection and irrigation by fusing census statistics with maps of agricultural land cover (Ramankutty and Foley, 1998; Frolking et al., 1999; Hurtt et al., 2001; Klein Goldewijk, 2001; Frolking et al., 2002; Leff et al., 2004; You and Wood, 2006).

Leff (2004) used such a technique to map the global extent of 18 major crops circa 1992. Few other datasets capture the global extent of individual crops (USDA/JAWF, 1994) and no datasets attempt to map all crops. Furthermore, no global datasets map crop yields—a key aspect of agriculture and a major factor in the biogeochemical changes associated with it.

Here we present a detailed database of global land-use practices describing the areas and yields of 175 individual crops circa the year 2000 at a 5 minute by 5 minute spatial resolution in latitude by longitude (or approximately 10 km by 10 km). We also present the data for these 175 crops (Table 1). These datasets are the combination of a new gridded map of global croplands for the year 2000 (Ramankutty et al., submitted as companion paper) with agricultural statistics representing thousands of individual administrative units throughout the world.

In the following sections we discuss the methodology and results for individual crops. In subsequent sections we use these data to estimate agricultural net primary production and describe patterns of broad physiological crop types.

2. Agricultural Inventory Data

We collected agricultural census and survey information on the areas and yields of 175 crops from the smallest political units reasonably obtainable for 206 countries (Table 2, Figure 1). Data availability varied for different crops within each country, with most countries having sub-national statistics for some crops but national statistics for others.

Sub-national data are one or two administrative levels below the national (i.e. state/province and county/district). These include 2,299 political units one level below the national from 150 countries, and 19,751 units two levels below for 73 countries. The largest single source of sub-national data is Agro-MAPS, a joint project between the United Nations Food and Agriculture Organization (FAO), the International Food Policy Research Institute (IFPRI), and the Center for Sustainability and the Global Environment (SAGE) (FAO, 2006b). Agro-MAPS is a collection of sub-national statistics on crop area, production, and yield for most countries in the world. For some crops, however, the Agro-MAPS data was missing or insufficiently detailed. To cover these gaps, we collected additional data from national census agencies and agricultural surveys. In particular, we turned to additional censuses and surveys to ensure county level data for the largest countries, including Brazil, Argentina, Mexico, Canada, India, the United States, and China. In certain instances, we were only able to obtain sub-national information on major crop groups (e.g. fruits or vegetables), which we used to proportionally distribute national level data from FAO to the state or county level.

When sub-national statistics were unavailable, we relied on national figures from the Food and Agriculture Organization's Statistical Databases (FAO, 2006a). We collected independent national level data for four countries that were absent from FAO—Afghanistan, Iraq, Somalia, and Taiwan.

FAOSTAT is the most widely recognized standard for national level agricultural statistics. We accordingly adopted FAOSTAT's classification system and reclassified all other data to match its definitions of the 175 individual crops, area, and yield. Area refers to the area of the harvest expressed in hectares. Areas harvested multiple times in a single year are therefore counted more than once. Yields are in metric tons per harvested hectare, and equal the annual total production in a political unit divided by the total harvested area.

Once all of the area and yield data were standardized in a single database, we attempted to correct for the kinds of errors that frequently arise in agricultural censuses and surveys from uneven data collection, misreporting, or incorrect tabulation. First, we aggregated the county level area for each crop to the state level. We then compared the sum of all of the counties with the state total reported in the agricultural statistics, and decided not to use the county data if the county sum was off by more than a factor of 2 from the reported state total (i.e. less than 50% or greater than 200%). Then we repeated the procedure by calculating the country total from the sub-national area data (i.e. the counties in each state that passed the first filter, plus the reported totals of the remaining states). We chose to use the sub-national data only if the total was between 50% and 200% of the FAOSTAT's national total. Otherwise, we simply used the reported national figures from FAOSTAT.

To screen the yield data for each crop, we excluded all values greater than 4 standard deviations from the regional mean (Africa, Asia, Europe and Central Asia, the Middle East, Oceania, North America, or South America), and all yield values that were less than 10% of the national average yield.

After correcting the area and yield data for individual years from 1990-2003, we averaged data from multiple years to get a single representative value for circa the year 2000. The single value came from the average of all years available between 1997 and 2003. If no data were available between these years, we used the average of years between 1990 and 1996. In order to keep our estimates as close to the year 2000 as possible, we avoided data prior to 1990. For a very small number of cases, the agricultural statistics explicitly indicated missing data or implicitly did so by giving the yield but not the area. We interpolated values into political units with missing area after mapping the database to a grid, as described in the following section.

3. Methods

We mapped the agricultural inventory data onto a grid by spatially disaggregating it using a map showing the fraction of each grid cell covered by cropland (Ramankutty et al., submitted as companion paper). We distributed the area of each crop over the cropland map in three steps. First, we used a gridded map of the political units represented in the agricultural inventory data to calculate the total cropland area in each political unit. Second, we determined the ratio of the crop area to total cropland in each political unit by dividing the crop area in the inventory data by the total cropland area in the same political unit calculated in the first step. Finally, we calculated the proportion of crop area in each grid cell by multiplying the data set of cropland proportion by the ratio of crop area to cropland in the political unit of that grid cell, as calculated in the second step. The procedure can therefore be represented as:

$$fcrop_{xy} = fcropland_{xy}\left(\frac{crop_{pu}}{cropland_{pu}}\right)$$

where $cropland_{pu}$ is the total cropland area calculated for each political unit, $crop_{pu}$ is the total crop area in each political unit from the agricultural inventory data, $fcropland_{xy}$ is the proportion of cropland in each grid cell from the spatial cropland dataset, and $fcrop_{xy}$ is the map of crop area as a fraction of each grid cell.

The crop area of the final map was set to zero when the agricultural inventory made no reference to a crop in a particular political unit, as mentioned in the previous section. We used the gridded map to estimate these missing data points by interpolating values from surrounding grid cells. We first calculated the ratio of crop area to cropland in each grid cell that did have agricultural inventory data by dividing the map of crop area by the map of total cropland. We then used a 3x3 filter to interpolate the resulting ratio of crop area to total cropland into cells with missing data to a distance of 2 degrees (~220 km). Lastly, we multiplied the interpolated values in each grid cell that was missing data by the cropland fraction of that grid cell. Grid cells missing data more than 2 degrees away from cells with data remained null.

After making a grid of crop areas, we created a grid of crop yields by disaggregating the yield from the smallest political unit with available data in the agricultural inventory. Unlike areas, yield data was disaggregated simply by distributing the inventory data for each administrative unit uniformly to each pixel within that administrative unit. In other words, we preferentially assigned county level data to the grid wherever they were available. If state level yields were available and county level yields were not, then we used the state data. If neither state nor county level yields were available, we resorted to country level yields. We set the yield to null in grid cells with a crop area of zero.

Finally, we ensured that the country area and yield total from the grids were representative of growing patterns circa the year 2000 by scaling the area and yield grids so that their country totals matched the FAOSTAT 1997-2003 national average.

As mentioned earlier, the map of crop area represents the area harvested of each crop. Some crops are harvested multiple times per year, which means that the harvested area exceeds the physical area of the cropland that they are grown on. This multiple-cropping potential is constrained by the length of the growing season. Climate conditions and irrigation determine the length of the growing season, which may permit as many as three harvests per year (Dairymple, 1971). This upper limit on multiple cropping therefore provides a useful way to check our datasets and correct them if necessary.

We performed this check by comparing the total harvested area with the total cropland in each grid cell. We began by calculating the ratio of harvested area to total cropland in each grid cell to estimate a "harvest ratio"; since the category croplands includes fallow land, our estimated harvest ratio is likely an underestimate of the true harvest ratio. We then compared this harvest-ratio with the multiple-cropping potential in each grid cell, which was estimated differently for rainfed and irrigated regions.

In rainfed regions we derived the multiple cropping potential from FAO and IIASA's Global Agroecological Zone Assessment (Fischer et al., 2000), which uses climate data to map the potential number of harvests under rainfed conditions without irrigation. The GAEZ map of 'multiple cropping zones' under rainfed conditions assigns one of nine zones to a 5 minute by 5 minute grid, ranging from ‘no cropping’ to ‘triple cropping’. For our purposes, we used GAEZ’s value but assumed a minimum value of 1 where it indicated ‘no cropping’. Where GAEZ’s multiple cropping zones were ambiguous we assumed the most generous value (e.g. we assumed two rotations under the zone of limited double cropping).

Irrigated regions can generally sustain more rotations than rainfed agriculture—triple cropping is not uncommon. We therefore set the number of potential rotations to 3 in irrigated grid cells identified by the global data set of fractional area equipped for irrigation (Siebert et al., 2005). Where the cropland area exceeded the area equipped for irrigation, we assigned the multiple cropping potential under rainfed conditions to the remainder of the cropland in the grid cell. The final multiple cropping potential of each cell therefore equaled the area weighted average potential of the irrigated and rainfed cropland.

In a minority of grid cells, our estimated harvest ratio exceeded the multiple cropping potential. In these cells, we constrained the total harvested area by scaling down the area of each crop so that the new harvest-ratio equaled the multiple cropping potential. Since our estimated harvest ratio is likely an underestimate of the true harvest ratio as mentioned earlier, this downscaling of harvested area is conservative.

4. Results and Evaluation

The final maps show the areas and yields of all 175 crops and their 11 major groupings. Although this paper does not afford the space to show all of the figures, here we do present the final figures for all of the major groupings and a selection of several crops (Figures 3-5). The full collection of datasets will be available online at www.sage.wisc.edu. In addition to depicting area and yield, the online datasets also document the administrative level from which the area and yield data originated (i.e. country, state, or county).

We are aware of no other efforts that globally map crop yields and know of only two other attempts to map global crop distributions. The Joint Agricultural Weather Facility (JAWF) of the U.S. Department of Agriculture (USDA) conducted the first of these efforts for the early 1990s (USDA/JAWF, 1994). Unlike our study, the USDA presents qualitative, non-digitized maps of major and minor growing areas for 19 crops in most but not all countries. The second effort was the predecessor to our study (Leff et al., 2004), which mapped the global extent of 18 major crops circa 1992. Although the USDA (1994) and Leff et al. (2004) datasets use different methodologies and depict an earlier time than our datasets, the two other efforts do provide a sound basis for comparing broad regional patterns.

A comparison of the 14 crops included in both of the previous efforts revealed widespread agreement (Leff et al., 2004). (Comparisons, however, were not possible for countries for which the USDA lacked data.) Significant discrepancies in crop distributions, however, existed in some countries. The discrepancies were most notable in countries with no sub-national information, countries with large administrative districts, and for crops with small growing areas. We evaluated our maps in these areas where Leff et al. (2004) diverged from the USDA. The evaluation revealed that our maps generally agree with the USDA maps in these disputed areas, with some exceptions.

Although broad cultivation patterns generally change little on a decadal time scale, a portion of the differences between our maps and the USDA maps may result from the contraction of crops in some areas (e.g. barley in Russia) and their expansion in others (e.g. soybeans in Argentina and Brazil). The remaining discrepancies result from differences in methodology, source statistics, or inaccuracies in the croplands map that serves as the foundation for our maps. While it is difficult to isolate the most important of these factors, a growing region present in only one dataset suggests missing statistics in the second dataset. Soybeans in India, for example, correspond everywhere except the state of Gujarat, suggesting that our source statistics omitted this minor growing region.

The high-resolution of sub-national census statistics allows the emergence of fine patterns in crop distribution, which are particularly noticeable for crops that occupy narrow growing regions. For example, our maps reveal small pockets of groundnuts in the southern United States that are present in the USDA maps but missing in the Leff et al dataset. Crops in some countries, like maize in Argentina and Brazil, exhibit an even finer level of detail in our maps than in the USDA maps, while at the same time agreeing on general patterns of cultivation. The corroboration of the new datasets with the USDA maps indicates that the distribution of much more detailed sub-national statistics over the updated croplands map have resulted in a greatly improved product. Moreover, we now offer a much more comprehensive product of both area and yields for all 175 crops considered by FAO, in a digital format that can be used by other researchers.

5. Ecological Significance of Global Cropping Systems

The scientific community could significantly reduce uncertainties surrounding agriculture's role in global ecological systems with detailed information on land-use practices like crop selection, yield, and physiology. Here we synthesize the data on crop areas and yields to get a broad perspective on patterns of crop physiology and net primary production.

5.1 Major Crop Types

Global ecosystem models often characterize heterogeneous plant species into plant functional types (PFT) (Smith, 1993). Here we adapt the principle of plant functional types to classify diverse croplands into major crop types. Plant functional types (PFTs) characterize heterogeneous landscapes by classifying vegetation along physiological and structural distinctions. These classifications include physiognomy (herbaceous/shrub/tree), photosynthetic pathway (C3/C4), leaf habit (evergreen/deciduous), and leaf form (broadleaf/evergreen). PFTs successfully describe vegetation functioning where biome level classifications are insufficient.

Neither the climatically-constrained nor the satellite derived PFTs, however, pay much attention to croplands. Croplands occupy a significant portion of the terrestrial biosphere, play a disproportionate role in global biogeochemistry, and constitute the part of biosphere most essential to human-well being. Global ecosystem models stand to benefit from better cropland parameterization. As a starting point, we aggregate the 175 individual crops into major crop functional types: annual/perennial, herbaceous/shrub/tree, C3/C4, and leguminous/non-leguminous.

5.1.1 Annual and Perennial Crops

1.8 million km^2, or roughly 13% of the harvested area of all crops, are in perennial orchards, grasses, and plantations, making perennials an important but little understood part of agroecosystems. Annual and perennial crops have very different consequences for ecosystem function.

Perennial crops allocate a higher proportion of carbohydrate to their roots than annual crops, and better build soil organic carbon (SOC) because they deposit less organic matter on the surface where it more readily decomposes (Post and Kwon, 2000). Conversion of perennial natural vegetation into annual agriculture has been shown to result in a 30 year SOC loss of 30% in the total soil profile and 50% in the top 20 cm (Davidson et al., 1993; Ellert and Gregorich, 1996; Post and Kwon, 2000). In addition to improving carbon storage, perennial agriculture benefits water quality while mitigating soil erosion and greenhouse gas emissions (Boody et al., 2005).

We use longevity to distinguish perennial from annual crops (Figure 6). Therefore crops like potatoes are considered annuals because they are harvested within one season even though they could live for more than a year. Crops that live for more than one year under typical cultivation practices count as perennials. These include crops like bananas and plantains that send forth annual shoots but maintain a perennial rhizome. Grasses for forage and fodder do not obviously fall into one category or the other. We therefore divided the harvested area of grasses evenly between annuals and perennials.

Perennial crops are most prevalent in the tropics, particularly in Indonesia, Thailand, Malaysia, and Papua New Guinea. Often perennial crops produce high value products like coffee, cocoa, fruit, oil palm, and nuts for export. Prominent regions of temperate perennial cultivation include the fruit and nut orchards of Southeastern Australia, California, and the Iberian Peninsula.

5.1.2 Crop Physiognomy

Physiognomy, or life-form, is a structural classification that we divide into herbaceous crops (forbs and graminoids), shrubs, and trees (Figure 6). The 12.3 million km^2 of herbaceous crops dominate 91% of all harvested area. Annual crops are exclusively herbaceous and make up the bulk of this area. Perennial crops, however, assume each of the three life-forms. Although most agricultural statistics do not distinguish between annual and perennial grasses, the latter cover an estimated 1.1 million km^2. Woody perennial shrubs (0.4 million km^2) and trees (0.8 million km^2) constitute the remaining non-herbaceous 9% of global harvested area.

The spatial distribution of herbaceous and woody crops (i.e. shrubs and trees) mirrors annuals and perennials, except for the roughly 4% of the global harvested area in perennial graminoids (i.e. grasses). Although woody shrub and tree crops share much of the same range, they have distinct distributions. Shrubs are predominant in the coffee and cocoa growing regions of western and eastern Africa; the Central American countries south of Mexico; the eastern coast of Brazil; northern South America in Ecuador, Colombia, and Venezuela; and pockets of southeast Asia. Grapes and berry bearing shrubs dot small areas of the temperate countries.

Temperate tree crops, in the form of fruit and to a lesser extent treenuts, extend to higher latitudes than shrubs in China, Eastern Europe, and portions of the United States. Herbaceous crops, however, occupy much more area than either shrub or tree crops throughout the temperate zones. In contrast, tree crops are more important in the humid tropics and more prevalent than herbaceous crops in portions of Sumatra, most of Borneo, and the whole of New Guinea. Although fruit bearing orchards are present in these regions, coconuts and oil palm dominate. Indonesia cultivates one quarter of the world's coconuts area, and Indonesia and Malaysia together grow one half of all oil palm trees.

5.1.3 C3 and C4 Crops

Whether C3 or C4 plants dominate in a particular region has a major effect on the flux of CO_2, water, and energy between the land and the atmosphere, and the fractionation of atmospheric carbon isotopes (Lloyd and Farquhar, 1994; Still et al., 2003). Still et al.

(2003) estimate that 18% of global vegetation cover is C4. Our data shows that although C4 crops are few—maize, sorghum, millet, sugarcane, and some grasses—they comprise 3.2 million km^2, a disproportionate 24% of all harvested area and 17% of all C4 vegetation.

Earlier estimates of C3 and C4 crop distributions depend on national-level agricultural statistics (Collatz et al., 1998; Still et al., 2003). Here we use the spatial distribution of individual crops to map the total areas of C3 and C4 crops (Figure 6). (Excluded are three CAM crops: pineapple, agave, and sisal.) While most of the crops presented here are clearly C3 or C4, grasses may be either kind. Temperature, however, is a strong predictor of the distribution of C3 and C4 vegetation. The greater water-use efficiency of C4 plants gives them an advantage over C3 plants in hot, dry conditions. Following Collatz and Still, we differentiated C4 grasses from C3 by using a 10 minute resolution global climate dataset (New, 2002) to identify cells with a mean monthly temperature greater than 22 degrees C for at least one month. Although people cultivate grasses outside of optimal growing conditions, broad patterns of C3 and C4 grasses are likely to follow these patterns.

The greatest proportion of C4 crops occurs in three main regions: Central Mexico through the Yucatan Peninsula, the eastern portion of Southern Africa extending from South Africa to Mozambique and Zambia, and a huge swath of the Sahel running from Mauritania in the West to Ethiopia in the East. While maize grows in all three regions, sorghum and millet are particularly important in the two African C4 belts. Other hot spots appear in Western India, Venezuela, Manchuria, and Eastern Europe. C4 crops constitute at least 50% of all crops planted in the Corn Belt of the United States and in Northern Argentina and Southern Brazil. Maize, grown in rotation with soybeans, and fodder grass, produce animal feedstock in these two large regions.

Although aggregate statistics indicate the global importance of C4 crops, a spatial perspective reveals just how critical C4 crops are in arid, agriculturally marginal regions—the very regions with the least food security and greatest vulnerability to climate change. Complicating the problem, it is unclear whether simultaneous changes in atmospheric CO_2, temperature, and precipitation will favor C3 or C4 crops in these already agriculturally marginal regions.

5.1.4 Leguminous Crops

Humans have doubled the flux of nitrogen into the terrestrial biosphere with important consequences for ecosystem function, water quality, and the production of the greenhouse gas nitrous oxide (Vitousek et al., 1997). Synthetic fertilizer, leguminous crops, fossil fuel combustion, and the mobilization of organic nitrogen are the biggest inputs. Legumes are the second most important source contributing ~40 Tg N yr^{-1}, or about half of the amount released through synthetic fertilizer. Knowledge of the location of leguminous crops could substantially improve understanding of the global spatial distribution of nitrogen cycling.

Worldwide legumes occupy 2.4 million km^2, or 18% of the global harvested area. We produced a map of leguminous crops by summing the harvested area of 20 individual crops (Figure 6): all pulses plus groundnuts, soybeans, alfalfa, and other leguminous forage crops. We included half of the area of mixed grasses & legumes.

Soybeans and alfalfa cover much of the central United States, the region near the border of Argentina and Brazil, and southern Australia. They are the primary protein source for livestock in these regions and are grown in rotation with maize, which supply livestock with the bulk of their energy requirements. By contrast, legumes are an important source of protein for humans in much of the rest of the world, most notably in the form of pulses in India and groundnuts in sub-Saharan Africa.

5.2 Cropland NPP

Net primary production (NPP) is a primary determinant of the C flux into the terrestrial biosphere. While studies have used agricultural statistics to derive global totals (Rojstaczer et al., 2001; Imhoff et al., 2004), no spatial estimates of global cropland net primary production exist. Spatial distribution of cropland NPP, however, is needed for improved carbon budget calculations and assessments of the potential for C sequestration to offset C emissions. Maps of cropland NPP could enhance spatial descriptions of terrestrial sources and sinks, through both tracer-transport inversion methods and land-based inventories (Pacala et al., 2001).

No global datasets and few regional studies of cropland NPP exist. Although satellites provide a tool for estimating global NPP, croplands are coincident with other kinds of vegetation, making it difficult to differentiate the two using remote-sensing. Statistical and process-based models are the second major method to estimate global NPP, but are generally limited to natural vegetation based on temperature, precipitation, and growing degree days, except for one recent study (Bondeau et al., accepted). Global and regional scale estimates of cropland NPP therefore must rely on census and survey data—but these data measure agricultural production, not NPP.

Prince et al. (2001) derived NPP measurements from agricultural production data by collecting county-level statistics of individual crops in the Midwest U.S. from the U.S. National Agricultural Statistics Service (USDA, 2002). They derived NPP by applying crop-specific factors to agricultural production and summing the result. Several studies have used this method to obtain estimates over time for the entire U.S (Hicke and Lobell, 2004; Hicke et al., 2004; Bradford et al., 2005). These approaches, however, have not been extended globally, nor have they been used to produce spatially-explicit, gridded products. We adapted these earlier methods to our gridded crop dataset to produce a global map of cropland NPP using the following equations:

$$NPP_i = \frac{EY_i \times DF_i \times C}{HI_i \times RS_i}$$

$$NPP = \sum_{i=1}^{175} \left(\frac{NPP_i}{fcrop_i} \right)$$

where *i* is the specific crop, *NPP* is net primary production, *EY* is the metric tons of economic yield per hectare, *DF* is the dry proportion of the economic yield, and *C* is the carbon content (0.45 g C g dry matter^{-1}). *HI* refers to the harvest index, a standard measure of the proportion of total aboveground biological yield allocated to the economic yield of the plant (Donald and Hamblin, 1976; Hay, 1995). The root:shoot ratio, *RS*, indicates the ratio of below to aboveground production. Finally, *fcrop* is the crop area as a proportion of the grid cell.

The crop specific factors vary slightly in the literature. They also vary with cultivars and growing conditions (Hay and Gilbert, 2001). Much of the increase in wheat yield over the past century, for example, is from the selection of higher NPP allocation to the seed (Sinclair, 1998). In contrast, increases in maize yield since 1950 have resulted from the development of cultivars that can withstand greater planting densities, while the harvest index of maize has remained constant (Sinclair, 1998). The harvest index of temperate maize also remains constant under different growing conditions (Hay and Gilbert, 2001). However, in a survey of tropical varieties of maize in Mexico and Malawi, Hay and Gilbert (1995) found that harvest indices were not highly heritable and fluctuated with season, management, and environmental conditions. Nevertheless, the application of typical values found in the literature to average yields approximates the distribution of global cropland NPP (Figure 6).

Four regions stand out as having the highest cultivated NPP on Earth: Western Europe; eastern Asia, including Japan, South Korea, and China; the Central US; and, to a lesser extent, southern Brazil and northern Argentina. These are the only large cultivated areas on the planet with NPP greater than 1.0 kg m^{-2}. The highest rates of all exceed 2.0 kg m^{-2} in the countries of Northern Europe bordering the North Sea. Especially intensive agriculture, usually associated with irrigation, attains comparable rates in a smaller areas scattered throughout the world, including New Zealand, Israel, Egypt, Saudi Arabia, California, Oregon, and Washington in the western US, Java, and pockets of Columbia, and India, and Mexico.

6. Discussion & Conclusions

The impact of agriculture on the biosphere is well documented. Agriculture has transformed entire continents and in the process driven massive changes in the physics, energy flows, and biogeochemical cycling of the planet (Foley et al., 2005). Documentation of agricultural impacts is therefore crucial to global change science and to securing human-well being in a transformed biosphere.

Thus far, knowledge about agriculture's impact has largely confined itself to global, or at best country-level totals. Aggregate figures hint at the magnitude of agricultural impacts but by themselves are unable to locate altered ecosystems, threatened people, and overlapping forces of change. Progress on these fronts depends on high-quality agricultural maps, but agriculture itself is heterogeneous. Different crops and farming practices have a real effect on carbon storage, nitrous oxide emissions, and the vulnerability of food production to climate change.

Unfortunately few global datasets describe agricultural land use and few global ecosystem models incorporate it, despite the fact that agroecosystems are vital to human-well being. The gaps are many: fertilizer inputs, planting and harvesting dates, tenure-practices, crop rotations, pesticide application, tillage practices, and so on. Foremost among these gaps—and one that provides a foundation for the development of other datasets—is a simple question, what grows where?

Remote-sensing has difficulty distinguishing crops at a global-scale but can identify spatial patterns of land cover. On the other hand, sub-national statistical surveys capture land-use practices like crop selection but do not describe their spatial extent. A fusion, however, of agricultural land-cover maps derived from remote-sensing with statistical surveys can help map agricultural land use across the world. In this paper, we refine that technique by using a recent map of global croplands (Ramankutty et al., submitted as companion paper) to distribute sub-national census data of individual crops. The resultant datasets map the extent of major crops using a richer compilation of sub-national data than in previous studies. These datasets are the first to map the area and yield of the Food and Agriculture Organization's 175 standardized crops at a global scale.

Standardizing statistical surveys has an inherent risk of misconstruing the definitions of diverse datasets. This is especially true of the production data used to determine yields, which often assume different units among countries that do not also disclose the exact units of measurement. To mitigate this risk we scaled the national totals to match FAOSTAT. Countries with extensive statistical sources report most crops at the state or county level. Other countries with limited resources may report data only at the national level, particularly for minor crops. Although we could not eliminate these discrepancies, we did record them by creating a gridded layer indicating whether the source data was national, state, or county. In addition, the satellite imagery used to distribute the crop data is less well suited to perennial tree and shrub crops than it is to herbaceous annuals. Although it is likely that tree and shrub crops are coincident with the base croplands map, we cannot state so with confidence everywhere.

Despite these limitations, four-fifths of the global harvested area is from sub-national sources, and the predominant form of this area is the herbaceous annual crops best captured by satellites. The reiteration of proven methods used to calculate the base croplands map, the high resolution of the sub-national statistics, and comparisons with other datasets indicate that these maps would be valuable inputs to global ecosystem models. Potential studies range the effect of climate change on food security to the influence of land-use practices on the global nitrogen cycle. Future research could extend these data through time to document historical crop area and yield changes, and use them to distribute data on additional types of agricultural land use.

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Figure Captions

Figure 1. Political units. The map shows the political units used in the crop datasets. These include 206 countries, 2,299 political units one level below the country level (state or province) from 150 countries, and 19,751 units two levels below the country level (county or district) for 73 countries.

Figure 2. Flowchart of the methodology used to create the area and yield maps. The boxes with sharp corners depict tabular datasets, and the boxes with rounded corners represent gridded datasets. We produced the final area and yield maps by first creating a database from various sources of agricultural statistics, and then used a map of croplands (Ramankutty, submitted as companion paper) to distribute these data spatially.

Figure 3. Crop areas and yields. Here we show only four (maize, rice, wheat, and soybeans) of the 175 individual crops. The maps show the harvested area of each crop as the proportion of each grid cell, and crop yields in tons per hectare.

Figure 4-5. Crop group areas. We aggregated the 175 individual into 11 major FAO crop groups: cereals, forage crops, oilcrops, fiber crops, fruit, vegetables, pulses, sugar crops, and roots & tubers (plus treenuts and miscellaneous crops, which do not appear here).

Figure 6. Major crop types and net primary production. The first four maps depict the harvested area of four major physiological crop types as a proportion of the harvested area of all crops: Perennial vs Annual Crops, Herbaceous vs. Woody Crops, Leguminous vs Non-Leguminous Crops; The final map depicts Crop Net Primary Production (NPP). Here we calculated the NPP of croplands by transforming the yield of each crop into NPP, and then performing an area-weighted average of the NPP of all crops in each grid cell.

Tables

Table 1. Crop designations: major group, annual/perennial, herbaceous/shrub/tree

Crop	Group	Annual/Perennial	Herbaceous/Shrub/Tree
Barley	Cereals	annual	herbaceous
Buckwheat	Cereals	annual	herbaceous
Canary Seed	Cereals	annual	herbaceous
Cereals, other	Cereals	annual	herbaceous
Fonio	Cereals	annual	herbaceous
Maize	Cereals	annual	herbaceous
Millet	Cereals	annual	herbaceous
Mixed Grain	Cereals	annual	herbaceous
Oats	Cereals	annual	herbaceous
Pop Corn	Cereals	annual	herbaceous
Quinoa	Cereals	annual	herbaceous
Rice	Cereals	annual	herbaceous
Rye	Cereals	annual	herbaceous
Sorghum	Cereals	annual	herbaceous
Triticale	Cereals	annual	herbaceous
Wheat	Cereals	annual	herbaceous
Abaca (Manila Hemp)	Fiber	perennial	shrub
Agave Fibers, other	Fiber	perennial	shrub
Coir	Fiber	annual	herbaceous
Fiber Crops, other	Fiber	annual	herbaceous
Flax Fiber and Tow	Fiber	annual	herbaceous
Hemp Fiber and Tow	Fiber	annual	herbaceous
Jute	Fiber	annual	herbaceous
Jute-Like Fibers	Fiber	annual	herbaceous
Kapok Fiber	Fiber	perennial	tree
Kapokseed in Shell	Fiber	perennial	tree
Ramie	Fiber	perennial	shrub
Cotton	Fiber	annual	herbaceous
Sisal	Fiber	perennial	shrub
Alfalfa	Forage	annual	herbaceous
Beets for Fodder	Forage	annual	herbaceous
Cabbage for Fodder	Forage	annual	herbaceous
Carrots for Fodder	Forage	annual	herbaceous
Clover	Forage	other	herbaceous
Forage Products, other	Forage	other	herbaceous
Grasses, other	Forage	other	herbaceous
Green Oilseeds for Fodder	Forage	annual	herbaceous

Legumes, other	Forage	other	herbaceous
Maize for Forage and Silage	Forage	annual	herbaceous
Mixed Grasses & Legumes	Forage	other	herbaceous
Rye Grass for Forage and Silage	Forage	annual	herbaceous
Sorghum for Forage and Silage	Forage	annual	herbaceous
Swedes for Fodder	Forage	annual	herbaceous
Turnips for Fodder	Forage	annual	herbaceous
Vegetables & Roots for Fodder	Forage	annual	herbaceous
Apples	Fruit	perennial	tree
Apricots	Fruit	perennial	tree
Avocados	Fruit	perennial	tree
Bananas	Fruit	perennial	shrub
Berries, other	Fruit	perennial	shrub
Blueberries	Fruit	perennial	shrub
Carobs	Fruit	perennial	tree
Cashewapple	Fruit	perennial	tree
Cherries	Fruit	perennial	tree
Citrus Fruit, other	Fruit	perennial	tree
Cranberries	Fruit	perennial	shrub
Currants	Fruit	perennial	tree
Dates	Fruit	perennial	tree
Figs	Fruit	perennial	tree
Fruit Fresh, other	Fruit	perennial	tree
Fruit Tropical Fresh, other	Fruit	perennial	tree
Gooseberries	Fruit	perennial	shrub
Grapefruit and Pomelos	Fruit	perennial	tree
Grapes	Fruit	perennial	shrub
Kiwi Fruit	Fruit	perennial	tree
Lemons and Limes	Fruit	perennial	tree
Mangoes	Fruit	perennial	tree
Oranges	Fruit	perennial	tree
Papayas	Fruit	perennial	tree
Peaches and Nectarines	Fruit	perennial	tree
Pears	Fruit	perennial	tree
Persimmons	Fruit	perennial	tree

Pineapples	Fruit	perennial	shrub
Plantains	Fruit	perennial	shrub
Plums	Fruit	perennial	tree
Quinces	Fruit	perennial	tree
Raspberries	Fruit	perennial	shrub
Sour Cherries	Fruit	perennial	tree
Stone Fruit other	Fruit	perennial	tree
Strawberries	Fruit	perennial	shrub
Tangerines and Mandarins	Fruit	perennial	tree
Castor Beans	Oilcrops	annual	herbaceous
Coconuts	Oilcrops	perennial	tree
Groundnuts in Shell	Oilcrops	annual	herbaceous
Hempseed	Oilcrops	annual	herbaceous
Karite Nuts (Sheanuts)	Oilcrops	perennial	tree
Linseed	Oilcrops	annual	herbaceous
Melonseed	Oilcrops	annual	herbaceous
Mustard Seed	Oilcrops	annual	herbaceous
Oil Palm Fruit	Oilcrops	perennial	tree
Oilseeds, other	Oilcrops	annual	herbaceous
Olives	Oilcrops	perennial	tree
Poppy Seed	Oilcrops	annual	herbaceous
Rapeseed	Oilcrops	annual	herbaceous
Safflower Seed	Oilcrops	annual	herbaceous
Sesame Seed	Oilcrops	annual	herbaceous
Soybeans	Oilcrops	annual	herbaceous
Sunflower Seed	Oilcrops	annual	herbaceous
Tung Nuts	Oilcrops	perennial	tree
Anise, Badian and Fennel	Other	annual	herbaceous
Areca Nuts (Betel)	Other	perennial	tree
Chicory Roots	Other	annual	herbaceous
Cinnamon (Canella)	Other	perennial	tree
Cloves	Other	perennial	tree
Cocoa Beans	Other	perennial	shrub
Coffee, Green	Other	perennial	shrub
Ginger	Other	annual	herbaceous
Hops	Other	perennial	shrub
Kolanuts	Other	perennial	tree
Mate	Other	perennial	shrub
Natural Gums	Other	perennial	tree
Natural Rubber	Other	perennial	tree
Nutmeg, Mace and	Other	perennial	shrub

Cardamons			
Pepper	Other	perennial	shrub
Peppermint	Other	perennial	herbaceous
Pimento	Other	annual	herbaceous
Pyrethrum, Dried Flowers	Other	perennial	shrub
Spices, other	Other	perennial	tree
Tea	Other	perennial	shrub
Tobacco Leaves	Other	annual	herbaceous
Vanilla	Other	perennial	shrub
Bambara Beans	Pulses	annual	herbaceous
Beans, Dry	Pulses	annual	herbaceous
Broad Beans, Dry	Pulses	annual	herbaceous
Chick-Peas	Pulses	annual	herbaceous
Cow Peas, Dry	Pulses	annual	herbaceous
Lentils	Pulses	annual	herbaceous
Lupins	Pulses	annual	herbaceous
Peas, Dry	Pulses	annual	herbaceous
Pigeon Peas	Pulses	annual	herbaceous
Pulses, other	Pulses	annual	herbaceous
Vetches	Pulses	annual	herbaceous
Cassava	Roots&Tubers	annual	herbaceous
Potatoes	Roots&Tubers	annual	herbaceous
Roots and Tubers, other	Roots&Tubers	annual	herbaceous
Sweet Potatoes	Roots&Tubers	annual	herbaceous
Taro	Roots&Tubers	annual	herbaceous
Yams	Roots&Tubers	annual	herbaceous
Yautia	Roots&Tubers	annual	herbaceous
Sugar Beets	SugarCrops	annual	herbaceous
Sugar Cane	SugarCrops	annual	herbaceous
Sugar Crops, other	SugarCrops	annual	herbaceous
Almonds	Treenuts	perennial	tree
Brazil Nuts	Treenuts	perennial	tree
Cashew Nuts	Treenuts	perennial	tree
Chestnuts	Treenuts	perennial	tree
Hazelnuts (Filberts)	Treenuts	perennial	tree
Nuts, other	Treenuts	perennial	tree
Pistachios	Treenuts	perennial	tree
Walnuts	Treenuts	perennial	tree
Artichokes	Vegetables&Melons	annual	herbaceous
Asparagus	Vegetables&Melons	annual	herbaceous
Beans, Green	Vegetables&Melons	annual	herbaceous

Broad Beans, Green	Vegetables&Melons	annual	herbaceous
Cabbages	Vegetables&Melons	annual	herbaceous
Cantaloupes & other Melons	Vegetables&Melons	annual	herbaceous
Carrots	Vegetables&Melons	annual	herbaceous
Cauliflower	Vegetables&Melons	annual	herbaceous
Chillies & Peppers, Green	Vegetables&Melons	annual	herbaceous
Cucumbers and Gherkins	Vegetables&Melons	annual	herbaceous
Eggplants	Vegetables&Melons	annual	herbaceous
Garlic	Vegetables&Melons	annual	herbaceous
Green Corn (Maize)	Vegetables&Melons	annual	herbaceous
Lettuce	Vegetables&Melons	annual	herbaceous
Mushrooms	Vegetables&Melons	annual	herbaceous
Okra	Vegetables&Melons	annual	herbaceous
Onions, Dry	Vegetables&Melons	annual	herbaceous
Onions & Shallots, Green	Vegetables&Melons	annual	herbaceous
Peas, Green	Vegetables&Melons	annual	herbaceous
Pumpkins, Squash, Gourds	Vegetables&Melons	annual	herbaceous
Spinach	Vegetables&Melons	annual	herbaceous
String Beans	Vegetables&Melons	annual	herbaceous
Tomatoes	Vegetables&Melons	annual	herbaceous
Vegetables Fresh, other	Vegetables&Melons	annual	herbaceous
Watermelons	Vegetables&Melons	annual	herbaceous

Table 2. Country Data Sources

Country	**% of area from sub-national sources**	**Source**	**Comments**
Afghanistan	0%	FAO (2006c)	FAOSTAT has no data. Area and production data are available only for barley, maize, millet, rice, and wheat from FAO country profiles. Total roots&tubers and pulses from FAO country profiles assume the same

			proportions of individual crops as Pakistan.
Albania	56%	FAO (2006a), FAO (2006b)	
Algeria	80%	FAO (2006a), FAO (2006b)	FAOSTAT reports area but not yield for 'rye grass for forage and silage'. We use Spain's national yield as a proxy for this crop.
American Samoa	0%	FAO (2006b)	
Angola	32%	FAO (2006a), FAO (2006b)	
Antigua and Barbuda	0%	FAO (2006b)	
Argentina	98%	INDEC (2002), FAO (2006b)	We used national census statistics for 'alfalfa' in place of FAOSTAT.
Armenia	0%	FAO (2006b)	
Australia	94%	ABS (2003, 2005), FAO (2006b)	We exclude the ~22 million ha of 'mixed grasses&legumes' that FAOSTAT reports because neither the census nor the base cropland map includes this category.
Austria	70%	FAO (2006a), FAO (2006b)	
Azerbaijan	0%	FAO (2006b)	
Bahamas	0%	FAO (2006b)	
Bahrain	0%	FAO (2006b)	
Bangladesh	80%	FAO (2006b), FAO (2006d)	
Barbados	0%	FAO (2006b)	
Belarus	13%	FAO (2006a), FAO (2006b)	
Belgium	73%	FAO (2006a), FAO (2006b)	
Belize	67%	FAO (2006a), FAO (2006b)	
Benin	82%	FAO (2006a), FAO (2006b), WRI (1995)	Sub-national data on aggregate 'fruit' and 'pulses' used to distribute national data of individual crops (except bananas and

			plantains).
Bermuda	0%	FAO (2006b)	
Bhutan	65%	FAO (2006b), FAO (2006d)	
Bolivia	73%	FAO (2006a), FAO (2006b)	
Bosnia and Herzegovina	0%	FAO (2006b)	
Botswana	73%	FAO (2006a), FAO (2006b)	
Brazil	98%	FAO (2006b), IBGE (2003)	
British Virgin Islands	0%	FAO (2006b)	
Brunei Darussalam	0%	FAO (2006b)	
Bulgaria	80%	FAO (2006a), FAO (2006b)	
Burkina Faso	82%	FAO (2006a), FAO (2006b), WRI (1995)	Sub-national data on aggregate 'fruit' and 'pulses' used to distribute national data of individual crops (except bananas, plantains, cow peas, and bambara beans).
Burundi	0%	FAO (2006b)	
Cambodia	91%	FAO (2006b), FAO (2006d)	
Cameroon	59%	FAO (2006a), FAO (2006b), WRI (1995)	Sub-national data on aggregate 'fruit' and 'pulses' used to distribute national data of individual crops (except bananas, plantains, pineapples, and beans).
Canada	99%	FAO (2006b), Statistics Canada (2001)	We used national census statistics for 'alfalfa' and mixed grasses and legumes' in place of FAOSTAT. Canada is also the only country with three administrative levels below the national (province, census agricultural region, and census division).
Cape Verde	0%	FAO (2006b)	

Cayman Islands	0%	FAO (2006b)	
Central African Republic	78%	FAO (2006a), FAO (2006b), WRI (1995)	Sub-national data on aggregate 'fruit' and 'pulses' used to distribute national data of individual crops (except bananas and plantains).
Chad	96%	FAO (2006a), FAO (2006b), WRI (1995)	Sub-national data on aggregate 'fruit' and 'pulses' used to distribute national data of individual crops (except bananas, plantains, cow peas, and bambara beans).
Chile	50%	FAO (2006a), FAO (2006b)	
China	97%	FAO (2006b), Institute of Natural Resources and Regional Planning (1998), USDA (2006)	Sub-national data on aggregate 'fruit' and 'vegetables' used to distribute national level data of individual crops. Sub-national 'grain' (cereals+pulses) data used to distribute rye, buckwheat, triticale, barley, oats, other cereals, and pulses.
Cocos Is	0%	FAO (2006b)	
Colombia	68%	FAO (2006a), FAO (2006b)	
Comoros	0%	FAO (2006b)	
Congo, Dem Republic of	86%	FAO (2006a), FAO (2006b)	
Congo, Republic of	61%	FAO (2006a), FAO (2006b)	
Cook Islands	0%	FAO (2006b)	
Costa Rica	0%	FAO (2006b)	
Côte d'Ivoire	18%	FAO (2006a), FAO (2006b), WRI (1995)	Sub-national data on aggregate 'fruit' and 'pulses' used to distribute national data of individual crops (except bananas and plantains).
Croatia	0%	FAO (2006b)	
Cuba	6%	FAO (2006a),	

		FAO (2006b)	
Cyprus	87%	FAO (2006a), FAO (2006b)	
Czech Republic	66%	FAO (2006a), FAO (2006b)	
Denmark	0%	FAO (2006b)	
Djibouti	0%	FAO (2006b)	
Dominica	0%	FAO (2006b)	
Dominican Republic	0%	FAO (2006b)	
Ecuador	68%	FAO (2006a), FAO (2006b)	
Egypt	60%	FAO (2006a), FAO (2006b)	
El Salvador	48%	FAO (2006a), FAO (2006b)	
Equatorial Guinea	0%	FAO (2006b)	
Eritrea	8%	FAO (2006a), FAO (2006b)	
Estonia	0%	FAO (2006b)	
Ethiopia	71%	Central Statistical Authority (1992), FAO (2006b)	
Faeroe Islands	0%	FAO (2006b)	
Fiji Islands	0%	FAO (2006b)	
Finland	0%	FAO (2006b)	
France	65%	FAO (2006a), FAO (2006b)	
French Guiana	4%	FAO (2006a), FAO (2006b)	
French Polynesia	0%	FAO (2006b)	
Gabon	0%	FAO (2006b)	Sub-national data on aggregate 'fruit' and 'pulses' used to distribute national data of individual crops (except bananas and plantains).
Gambia	94%	FAO (2006a), FAO (2006b), WRI (1995)	Sub-national data on aggregate 'fruit' and 'pulses' used to distribute national data of individual crops (except bananas and plantains).
Georgia	0%	FAO (2006b)	
Germany	59%	FAO (2006a),	

		FAO (2006b)	
Ghana	61%	FAO (2006a), FAO (2006b), WRI (1995)	Sub-national data on aggregate 'fruit' and 'pulses' used to distribute national data of individual crops (except bananas, plantains, and cow peas).
Greece	78%	FAO (2006a), FAO (2006b)	
Grenada	0%	FAO (2006b)	
Guadeloupe	0%	FAO (2006b)	
Guam	0%	FAO (2006b)	
Guatemala	34%	FAO (2006a), FAO (2006b)	
Guinea	63%	FAO (2006a), FAO (2006b), WRI (1995)	Sub-national data on aggregate 'fruit' and 'pulses' used to distribute national data of individual crops (except bananas and plantains).
Guinea-Bissau	37%	FAO (2006a), FAO (2006b), WRI (1995)	Sub-national data on aggregate 'fruit' and 'pulses' used to distribute national data of individual crops (except bananas, plantains, and beans).
Guyana	43%	FAO (2006a), FAO (2006b)	
Haiti	0%	FAO (2006b)	
Honduras	46%	FAO (2006a), FAO (2006b)	
Hungary	67%	FAO (2006a), FAO (2006b)	
Iceland	0%	FAO (2006b)	
India	88%	AgriStat (2006), FAO (2006b)	Sub-national data on aggregate 'vegetables' used to distribute national data of individual crops (except cauliflower, cabbage, peas, onions, okra, and garlic).
Indonesia	67%	FAO (2006a), FAO (2006b), Pitono (2002)	
Iran	74%	FAO (2006a),	

		FAO (2006b)	
Iraq	95%	FAO (2006b), FAO (2006c)	FAOSTAT has no data. Area and production data are available only for individual cereal crops, dates, and sunflower seed from Agro-MAPS and FAO country profiles. Total roots&tubers and pulses from FAO country profiles assume the same proportions of individual crops as Iran.
Ireland	56%	FAO (2006a), FAO (2006b)	
Israel	0%	FAO (2006b)	
Italy	63%	FAO (2006a), FAO (2006b)	
Jamaica	1%	FAO (2006a), FAO (2006b)	
Japan	51%	FAO (2006b), FAO (2006d)	
Jordan	83%	FAO (2006a), FAO (2006b)	
Kazakhstan	84%	Gosudarstveni Committet Kazahskoi SSR po Statistike (1987)	Sub-national data on aggregate 'vegetables' used to distribute national data of individual crops. Difference between sum of sub-national data of individual cereals and total cereals used for barley. Census data only available for 1986, except sugarbeets, sunflower and potatoes for which more recent data exist.
Kenya	5%	FAO (2006a), FAO (2006b)	
Kiribati	0%	FAO (2006b)	
Korea, Dem People's Rep	0%	FAO (2006b)	
Korea, Republic of	0%	FAO (2006b)	
Kuwait	20%	FAO (2006a), FAO (2006b)	
Kyrgyzstan	0%	FAO (2006b)	

Laos	82%	FAO (2006b), FAO (2006d)	
Latvia	0%	FAO (2006b)	
Lebanon	29%	FAO (2006a), FAO (2006b)	
Lesotho	95%	FAO (2006a), FAO (2006b)	
Liberia	64%	FAO (2006a), FAO (2006b), WRI (1995)	Sub-national data on aggregate 'fruit' and 'pulses' used to distribute national data of individual crops (except bananas and plantains).
Libya	0%	FAO (2006b)	
Lithuania	47%	FAO (2006a), FAO (2006b)	
Luxembourg	0%	FAO (2006b)	
Macedonia	0%	FAO (2006b)	
Madagascar	83%	FAO (2006a), FAO (2006b)	
Malawi	67%	FAO (2006a), FAO (2006b)	
Malaysia	71%	FAO (2006a), FAO (2006b), Malaysian Palm Oil Board (2004)	
Maldives	0%	FAO (2006b)	
Mali	96%	FAO (2006a), FAO (2006b), WRI (1995)	Sub-national data on aggregate 'fruit' and 'pulses' used to distribute national data of individual crops (except bananas, plantains, cow peas, and bambara beans).
Malta	0%	FAO (2006b)	
Marshall Islands	0%	FAO (2006b)	
Martinique	0%	FAO (2006b)	
Mauritania	83%	FAO (2006a), FAO (2006b), WRI (1995)	Sub-national data on aggregate 'fruit' and 'pulses' used to distribute national data of individual crops (except bananas, plantains, and cow peas).
Mauritius	4%	FAO (2006a), FAO (2006b)	

Mexico	96%	FAO (2006b), INEGI (2002, 2004), SIAP (2005)	
Micronesia, Fed States of	0%	FAO (2006b)	
Moldova	0%	FAO (2006b)	
Mongolia	0%	FAO (2006b)	
Montserrat	0%	FAO (2006b)	
Morocco	80%	FAO (2006a), FAO (2006b)	
Mozambique	66%	FAO (2006a), FAO (2006b)	
Myanmar	51%	FAO (2006b), FAO (2006d)	
Namibia	74%	FAO (2006a), FAO (2006b)	
Nauru	0%	FAO (2006b)	
Nepal	77%	FAO (2006b), FAO (2006d)	
Netherlands	54%	FAO (2006a), FAO (2006b)	
New Caledonia	0%	FAO (2006b)	
New Zealand	0%	FAO (2006b)	
Nicaragua	85%	FAO (2006a), FAO (2006b)	
Niger	99%	FAO (2006a), FAO (2006b), WRI (1995)	Sub-national data on aggregate 'fruit' and 'pulses' used to distribute national data of individual crops (except bananas, plantains, cow peas, and beans).
Nigeria	92%	FAO (2006a), FAO (2006b), WRI (1995)	Sub-national data on aggregate 'fruit' and 'pulses' used to distribute national data of individual crops (except bananas, plantains, and cow peas). Use sub-national distribution when distribution even when total differs from FAOSTAT.
Niue	0%	FAO (2006b)	
Norway	0%	FAO (2006b)	

Oman	0%	FAO (2006b)	
Pakistan	83%	FAO (2006b), FAO (2006d)	
Panama	66%	FAO (2006a), FAO (2006b)	
Papua New Guinea	0%	FAO (2006b)	
Paraguay	31%	FAO (2006a), FAO (2006b)	
Peru	43%	FAO (2006a), FAO (2006b)	
Philippines	54%	FAO (2006b), FAO (2006d)	
Poland	64%	FAO (2006a), FAO (2006b)	
Portugal	50%	FAO (2006a), FAO (2006b)	
Puerto Rico	68%	FAO (2006a), FAO (2006b)	
Qatar	20%	FAO (2006a), FAO (2006b)	
Réunion	0%	FAO (2006b)	
Romania	73%	FAO (2006a), FAO (2006b)	
Russian Federation	94%	FAO (2006b), Goskomstat Rusii (1995), USDA (1999)	Sub-national data on aggregate 'vegetables' and pulses used to distribute national data of individual crops. Difference between sum of sub-national data of individual cereals and total cereals used for barley and oats.
Rwanda	69%	FAO (2006a), FAO (2006b)	
Saint Kitts and Nevis	0%	FAO (2006b)	
Saint Lucia	0%	FAO (2006b)	
Saint Vincent/Grenadines	0%	FAO (2006b)	
Samoa	0%	FAO (2006b)	
Sao Tome and Principe	16%	FAO (2006a), FAO (2006b)	
Saudi Arabia	69%	FAO (2006a), FAO (2006b)	
Senegal	98%	FAO (2006a), FAO (2006b),	Sub-national data on aggregate 'fruit' and

		WRI (1995)	'pulses' used to distribute national data of individual crops (except bananas, plantains, and cow peas).
Serbia and Montenegro	0%	FAO (2006b)	
Seychelles	0%	FAO (2006b)	
Sierra Leone	87%	FAO (2006a), FAO (2006b), WRI (1995)	Sub-national data on aggregate 'fruit' and 'pulses' used to distribute national data of individual crops (except bananas and plantains).
Singapore	0%	FAO (2006b)	
Slovakia	72%	FAO (2006a), FAO (2006b)	
Slovenia	0%	FAO (2006b)	
Solomon Islands	0%	FAO (2006b)	
Somalia	0%	FAO (2006b)	FAOSTAT has no data. Area and production data are available only for maize, sorghum, rice, wheat, and cotton from FAO country profiles. We estimated the area of other crops from Somali production statistics and Ethiopian yield (or Kenyan yield when Ethiopian unavailable).
South Africa	72%	Biggs and Scholes (2002), Statistics South Africa (2002)	
Spain	75%	FAO (2006a), FAO (2006b)	
Sri Lanka	78%	FAO (2006b), FAO (2006d)	
Sudan	63%	FAO (2006b)	
Suriname	93%	FAO (2006a), FAO (2006b)	
Swaziland	58%	FAO (2006a), FAO (2006b)	
Sweden	41%	FAO (2006a), FAO (2006b)	
Switzerland	0%	FAO (2006b)	

Syria	0%	FAO (2006b)	FAOSTAT does not report Taiwan separately from China.
Taiwan	0%	Council of Agriculture, Executive Yuan R.O.C. (2002)	
Tajikistan	0%	FAO (2006b)	
Tanzania	61%	FAO (2006a), FAO (2006b)	
Thailand	72%	FAO (2006b), FAO (2006d)	
Timor-Leste	0%	FAO (2006b)	
Togo	95%	FAO (2006a), FAO (2006b), WRI (1995)	Sub-national data on aggregate 'fruit' and 'pulses' used to distribute national data of individual crops (except bananas, plantains, and beans).
Tokelau	0%	FAO (2006b)	
Tonga	0%	FAO (2006b)	
Trinidad and Tobago	28%	FAO (2006a), FAO (2006b)	
Tunisia	89%	FAO (2006a), FAO (2006b)	
Turkey	81%	FAO (2006a), FAO (2006b)	
Turkmenistan	0%	FAO (2006b)	
Tuvalu	0%	FAO (2006b)	
Uganda	50%	FAO (2006a), FAO (2006b)	
Ukraine	61%	Bouzaher (1994), FAO (2006b), USDA (2004)	Sub-national data on aggregate 'vegetables' used to distribute national data of individual crops.
United Arab Emirates	0%	FAO (2006b)	
United Kingdom	64%	FAO (2006a), FAO (2006b)	
United States of America	100%	USDA (2002)	We did not include crops that did not appear in the census but did appear in FAOSTAT (green oilseeds for fodder and other grasses).
Uruguay	90%	FAO (2006a),	

		FAO (2006b)	
Uzbekistan	0%	FAO (2006b)	
Vanuatu	0%	FAO (2006b)	
Venezuela	69%	FAO (2006a), FAO (2006b)	
Viet Nam	76%	FAO (2006b), FAO (2006d)	
Wallis and Futuna Is	0%	FAO (2006b)	
Yemen	0%	FAO (2006b)	
Zambia	90%	FAO (2006a), FAO (2006b)	
Zimbabwe	70%	FAO (2006a), FAO (2006b)	
TOTAL	81%		

Figures

Figure 1.

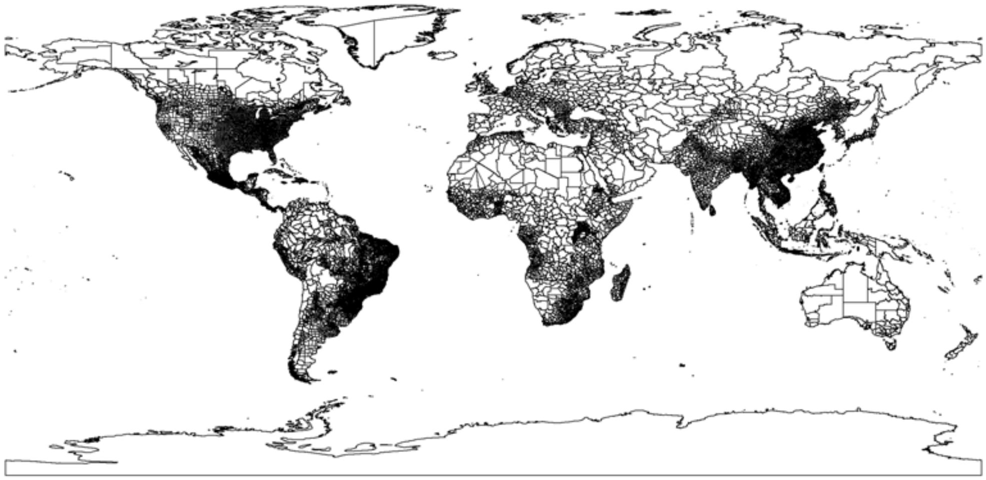


Figure 2.

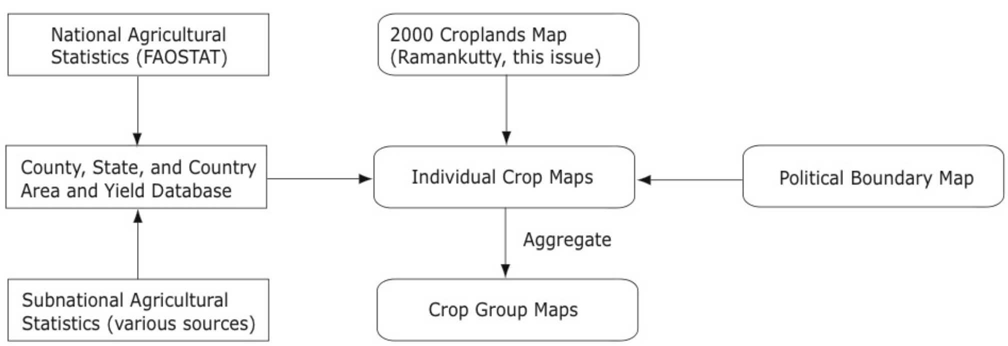


Figure 3.

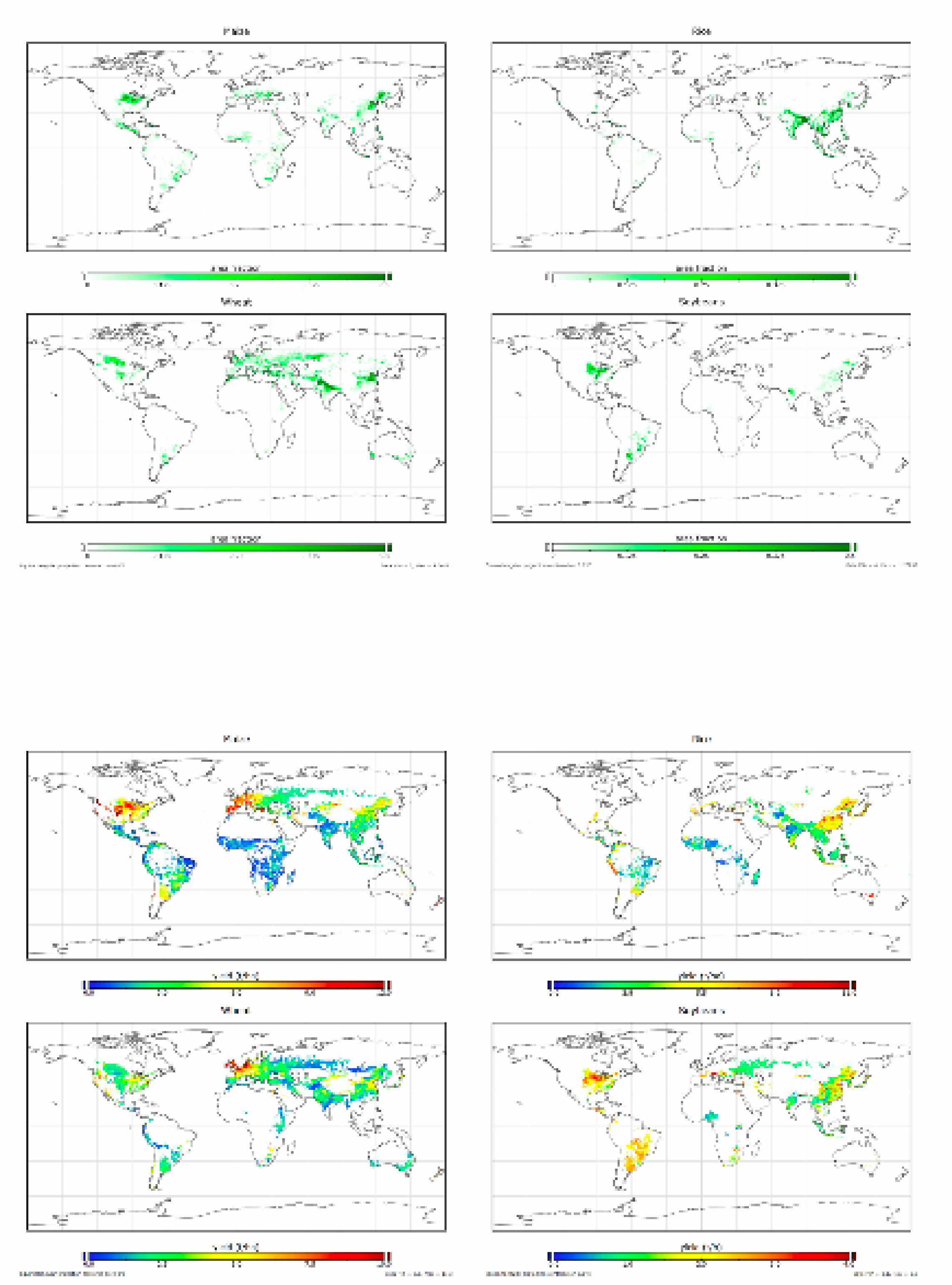


Figure 4.

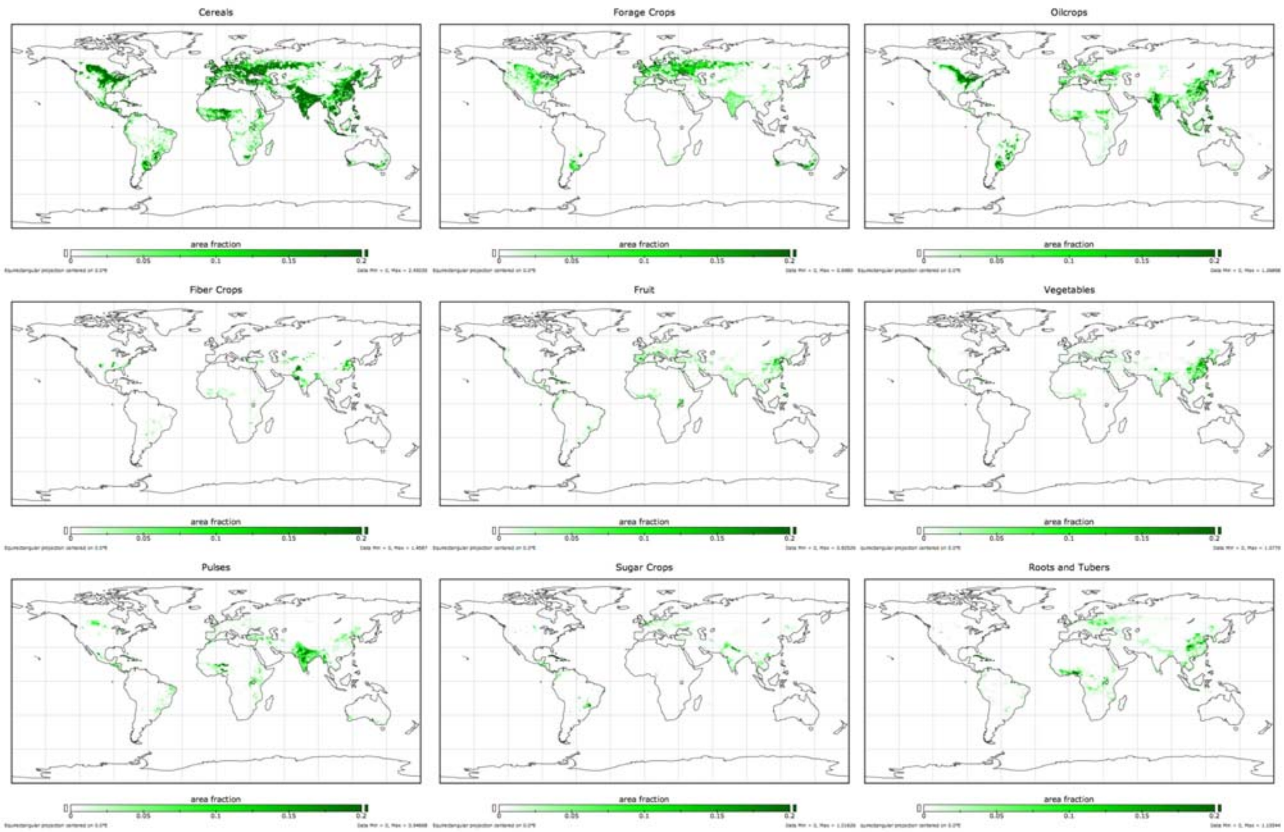
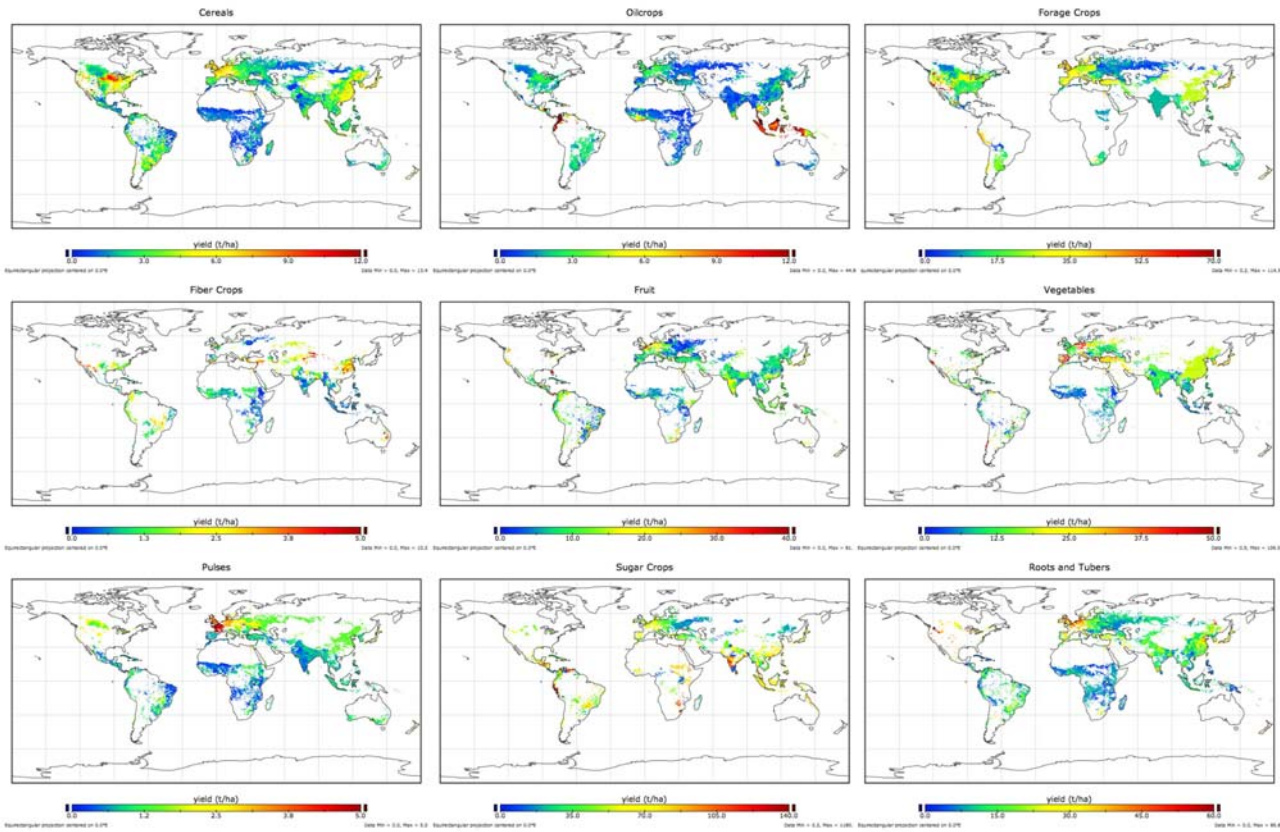

Cereals
Forage Crops
Oilcrops
Fiber Crops
Fruit
Vegetables
Pulses
Sugar Crops
Roots and Tubers
area fraction
0
0.05
0.1
0.15
0.2

Figure 5.



Cereals
Oilcrops
Forage Crops
yield (t/ha)
yield (t/ha)
yield (t/ha)
Fiber Crops
Fruit
Vegetables
yield (t/ha)
yield (t/ha)
yield (t/ha)
Pulses
Sugar Crops
Roots and Tubers
yield (t/ha)
yield (t/ha)
yield (t/ha)

Figure 6.