



***Development of GTAP version 10
Land Use and Land Cover database
for years 2004, 2007, 2011 and 2014***

by

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I. Background and Motivation

Understanding the challenges of achieving environmental sustainability goals given future demand for food, fiber and fuel requires economic models and databases that incorporate spatially explicit information on land use and land cover (LULC). The GTAP LULC database and its variants have been extensively used in a wide variety of applications aimed at examining the land-environment-energy nexus (Golub et al., 2012; Hertel et al., 2010; Johnson et al., 2019; Liu et al., 2014; Peña-Lévano et al., 2019, 2019; Stevenson et al., 2013; Taheripour et al., 2010; Taheripour & Tyner, 2012).

The first release of the GTAP LULC database combines geospatial data on land use and land cover into the version 6 GTAP database – benchmarked to year 2001 (GTAP LULCv.6). The methodology for creating and using this database is well documented (Lee et al., 2009; C. Monfreda et al., 2009; Sohngen et al., 2008). Succeeding updates of the GTAP LULC database (namely v.7 and v.8 for 2004 and v.8 for 2004, 2007) relied on readily available but aggregated GTAP LULCv.6 albeit using national-level data from FAOSTAT (2020) (Avetisyan et al., 2010; Baldos & Hertel, 2012). GTAP LULCv.9 is created directly from the latest, high-resolution (i.e. 5-minute) spatial land cover and land use maps in combination with national-level statistics (Baldos, 2017). This memorandum documents the development of the GTAP LULC v.10 which is based on the GTAP v10 database for years 2004, 2007, 2011 and 2014 (Aguiar et al., 2019). This update heavily relies on the methodology for creating GTAP LULCv.9 which downscales national-level land cover and crop production statistics from FAOSTAT (2020) using publicly available spatial data (see Appendix I).

II. Highlights of GTAP LULC v.10

a. Land cover

Figures 1, 2 and 3 illustrate global land cover area (in M ha) for cropland, pasture and forest (orange, blue and green figures) by region-AEZ for the years 2004, 2007, 2011 and 2014, respectively. Regions where cropland area are sizable (i.e. dark colored polygons) include U.S. (AEZ8 and AEZ10), Russia (AEZ8 to AEZ10), India (AEZ3), Indonesia (AEZ6), China (AEZ9 and AEZ12) and Australia (AEZ8). Pastureland cover hot spots are located in Australia (AEZ7),

Saudi Arabia (AEZ7), Brazil (AEZ5) and U.S. (AEZ8). Forest cover are relatively large in Russia (AEZ14 and AEZ15), Brazil (AEZ6), U.S. (AEZ10 and AEZ12), Democratic Republic of the Congo (AEZ6), China (AEZ 12) and Indonesia (AEZ6).

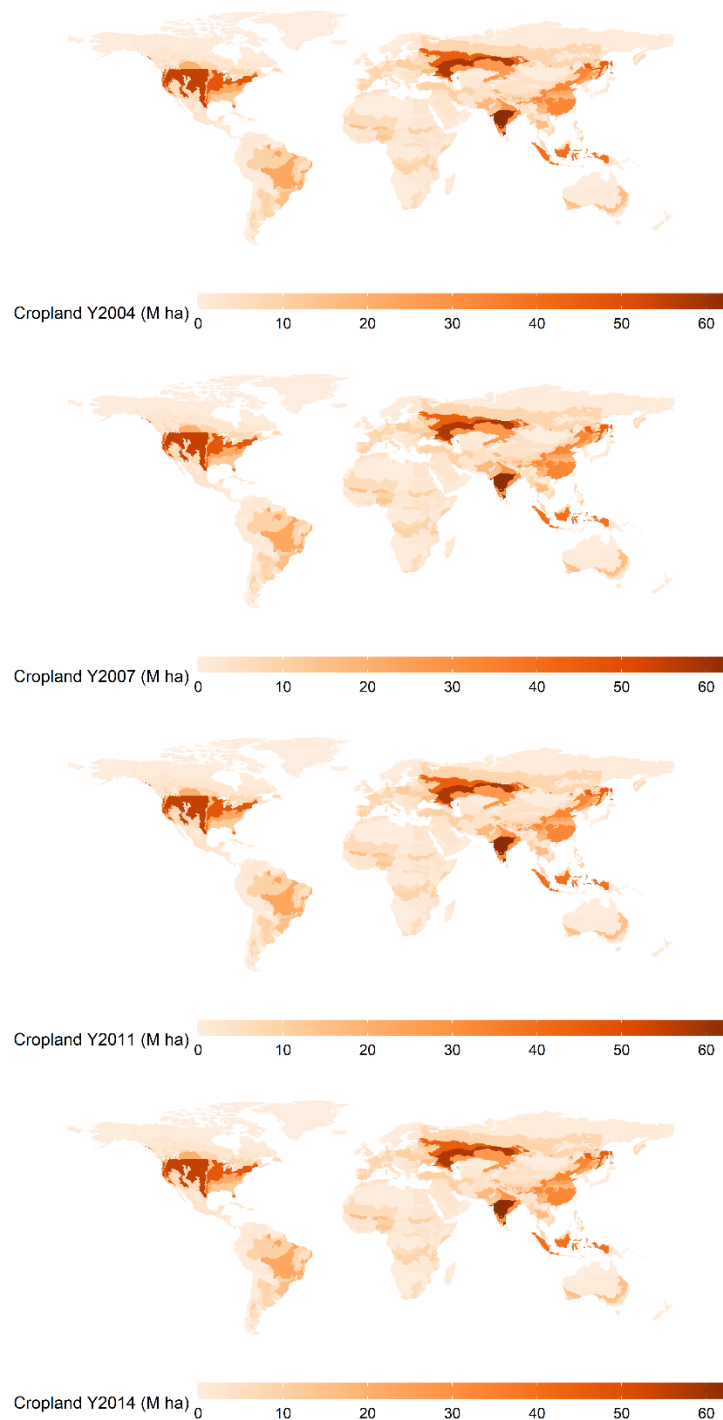


Figure 1. Global distribution of cropland by region and AEZ: 2004 2007 2011 2014

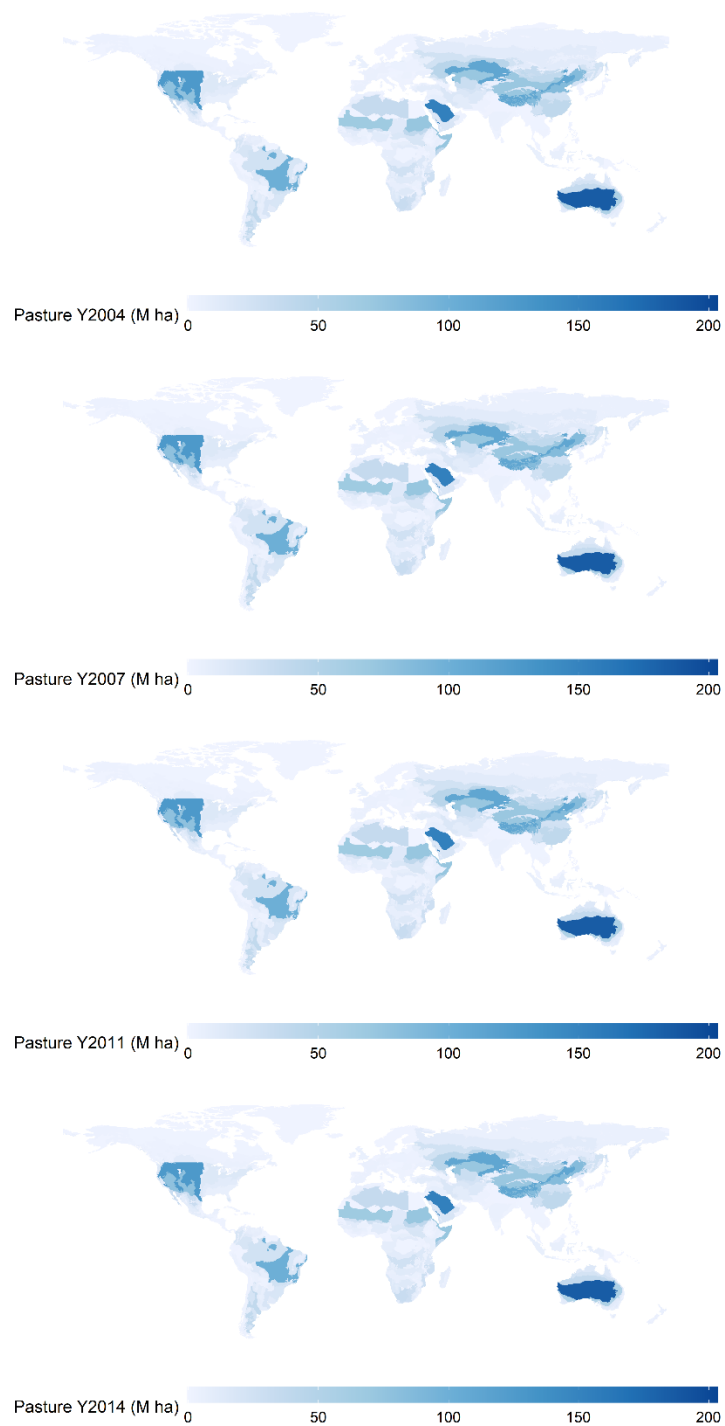


Figure 2. Global distribution of pastureland by region and AEZ: 2004 2007 2011 2014

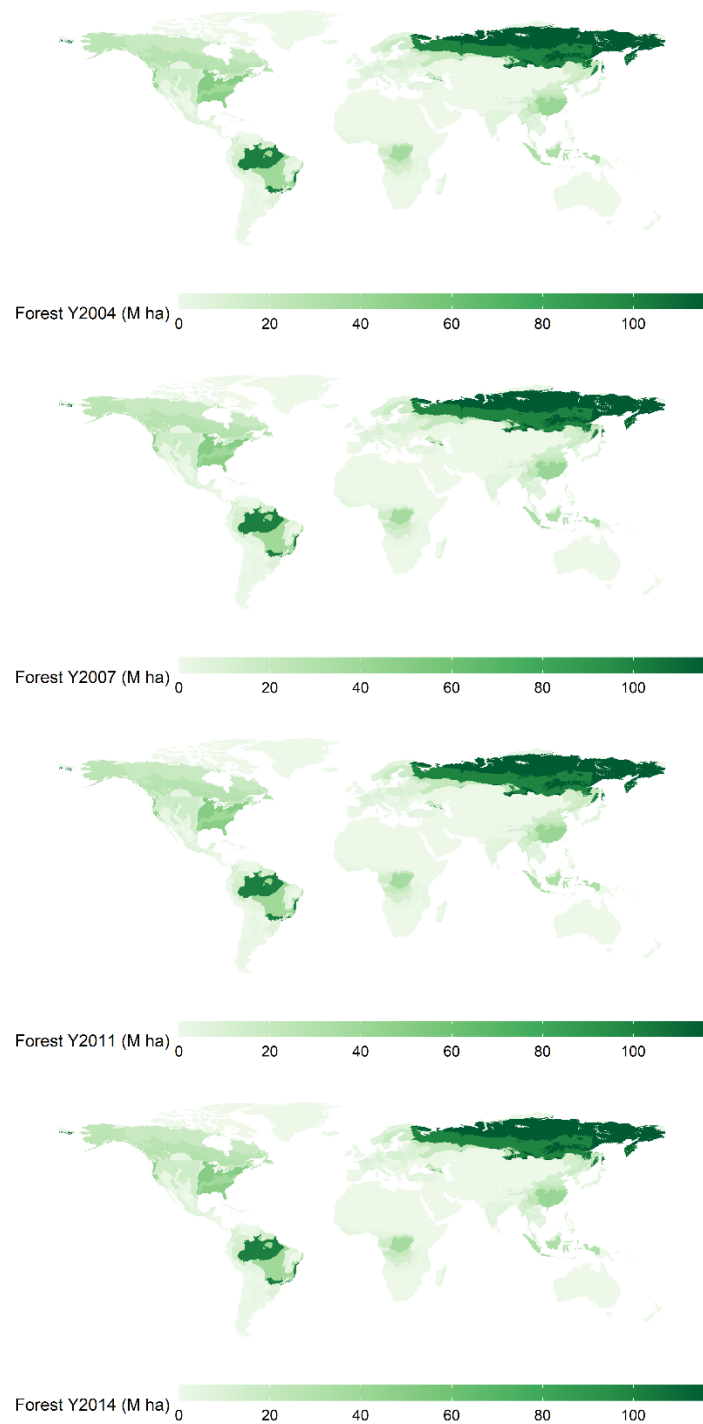


Figure 3. Global distribution of forests by region and AEZ: 2004 2007 2011 2014

Table 1 summarizes total land cover of cropland, pasture and forest – summed for all countries – for each AEZ given the benchmark years 2004, 2007 2011 and 2014. Globally, croplands are generally located in AEZ8, AEZ9 and AEZ10 (with annual average area at around 275, 230, 233 M ha, respectively). Note that prevailing thermal climates in AEZ8 to AEZ10 are classified as “Tropical cool to Temperate cool” with growing days ranging from 60 to 230 days. Pasturelands are mostly concentrated in AEZ7, AEZ8 and AEZ1 (835, 664, 265 M ha, respectively) while most of the world’s forests are in AEZ6, AEZ10 and AEZ15 (291, 217 and 215 Mha). Looking at the absolute changes between 2004 and 2007, global pasture area declined while cropland and forest cover increased slightly. AEZs where large gains in cropland area are observed include AEZ2 to AEZ5 (1.6, 1.7, 3.3 and 2.3 Mha) while AEZ8 to AEZ10 (-4.3, -2.1 and -2.5 Mha) experienced cropland cover reduction over this period. AEZ8 show strong reduction in pastureland area (-5.3 Mha) while it increased in AEZ1 and AEZ2 (3.6 and 1.7 Mha). Forest cover expanded in AEZ9 to AEZ11 (1.2, 2.0 and 1.1 Mha). Significant expansion in cropland cover and strong reductions in pasture cover are observed for the period 2007 to 2011. Cropland expanded rapidly in AEZ3 to AEZ6 (2.4, 4.7, 2.4 and 4.8 Mha) while AEZ1, AEZ7 and AEZ10 show notable reduction in pasture cover over this period (-1.2, -4.3 and -1.5 Mha, respectively). Change in forest cover are generally mixed with area increasing slightly in AEZ8 to AEZ11 (0.6, 0.8, 2.0, and 0.9 Mha) and declining in AEZ4 to AEZ6 (-1.2, -0.8 and -1.6 Mha). Over period 2011 to 2014, gains in cropland cover is observed while pasture cover continues to decline sharply at the global level. Cropland expanded rapidly in AEZ4 to AEZ6 (5.3, 3.1 and 1.7 Mha) while AEZ7 to AEZ11 (-12.4, -4.8, -1.5, -2.5 and -1.3 Mha) show reduction in pasture cover over this period. Similar to the period 2007 to 2011, changes in forest cover are generally mixed with area increasing slightly in AEZ10 and AEZ11 (1.2 and 0.4 Mha, respectively) and declining in AEZ4 to AEZ6 (-0.5, -0.9 and -0.8 Mha).

Land cover for cropland, pasture and forest for selected GTAP regions are listed in Table 2. Between 2004 and 2007, cropland cover in these regions are generally declining particularly in the U.S., China, Australia and Canada (-6.7, -1.9, -2.5 and -1.1 Mha). Australia and the US experienced strong increases in pasture cover (6.0 and 6.6 Mha) while forest cover in US, Canada and China also increased (1.5, 0.6 and 0.9 Mha). For the period 2007 to 2011, cropland cover in Australia and Indonesia increased (8.5 and 3.5 Mha). Pasture cover in Australia declined significantly (-10.8 Mha) while in Brazil and the US pasture area grew over this period (1.5 and 2.1 Mha). Forest cover declined in Brazil and Indonesia (-0.5 and -0.9 Mha) while it increased in

the US and in Canada (1.9 and 0.7 Mha). From 2011 to 2014, cropland and forest cover were relatively stable across these key countries but pasture cover in Australia shrunk significantly over this period (-21.9 Mha).

Table 1. Total area and relative changes in land cover categories by AEZ: 2004, 2007, 2011, 2014

Area (in M ha)	2004			2007			2011			2014			Diff: 2007 - 2004			Diff: 2011 - 2007			Diff: 2014 - 2011		
	Crop	Pasture	Forest	Crop	Pasture	Forest	Crop	Pasture	Forest	Crop	Pasture	Forest	Crop	Pasture	Forest	Crop	Pasture	Forest	Crop	Pasture	Forest
AEZ1	14.1	263.5	0.0	14.5	267.1	0.0	14.8	265.9	0.0	15.2	263.6	0.0	0.4	3.6	0.0	0.4	-1.2	0.0	0.4	-2.3	0.0
AEZ2	55.7	157.0	1.3	57.3	158.7	1.3	58.9	158.0	1.3	60.1	156.5	1.3	1.6	1.7	0.0	1.6	-0.7	0.0	1.3	-1.4	0.0
AEZ3	107.6	180.5	19.9	109.2	180.9	19.9	111.7	180.3	20.0	112.1	179.3	20.2	1.7	0.3	0.0	2.4	-0.6	0.1	0.4	-0.9	0.2
AEZ4	134.5	199.4	84.1	137.8	199.4	83.3	142.5	199.5	82.0	147.8	199.4	81.5	3.3	0.0	-0.8	4.7	0.1	-1.2	5.3	-0.1	-0.5
AEZ5	95.6	193.9	146.7	97.9	193.5	145.9	100.3	194.2	145.1	103.4	195.7	144.1	2.3	-0.4	-0.8	2.4	0.8	-0.8	3.1	1.4	-0.9
AEZ6	84.6	86.6	292.4	85.3	86.6	292.0	90.1	86.7	290.4	91.8	87.8	289.7	0.7	0.1	-0.4	4.8	0.1	-1.6	1.7	1.1	-0.8
AEZ7	55.0	840.8	3.1	54.9	840.3	3.0	54.0	836.1	2.9	54.5	823.6	3.0	-0.1	-0.5	-0.1	-0.9	-4.3	0.0	0.5	-12.4	0.0
AEZ8	278.3	667.8	26.9	274.1	662.5	27.1	274.0	664.7	27.7	274.5	659.9	27.9	-4.3	-5.3	0.2	0.0	2.2	0.6	0.4	-4.8	0.2
AEZ9	230.3	227.5	106.5	228.3	226.5	107.7	230.0	225.7	108.4	230.1	224.2	108.7	-2.1	-1.1	1.2	1.8	-0.7	0.8	0.1	-1.5	0.2
AEZ10	234.9	146.7	214.5	232.4	146.6	216.5	232.1	145.2	218.5	231.9	142.7	219.7	-2.5	-0.1	2.0	-0.3	-1.5	2.0	-0.2	-2.5	1.2
AEZ11	93.6	82.8	104.5	93.1	83.4	105.6	92.8	83.2	106.5	93.0	81.9	106.9	-0.6	0.6	1.1	-0.3	-0.2	0.9	0.1	-1.3	0.4
AEZ12	90.3	135.0	117.4	91.0	135.4	117.6	92.8	135.0	117.4	93.7	134.8	117.4	0.7	0.4	0.2	1.8	-0.4	-0.2	0.9	-0.2	-0.1
AEZ13	1.0	50.0	4.6	1.0	50.2	4.6	1.0	50.1	4.6	1.0	49.9	4.6	0.0	0.2	0.0	0.0	-0.1	0.0	0.0	-0.2	0.0
AEZ14	3.8	64.8	177.2	3.8	65.1	177.1	3.7	65.0	177.1	3.7	64.7	177.1	-0.1	0.3	0.0	-0.1	-0.1	0.0	0.0	-0.2	0.0
AEZ15	15.5	23.7	214.6	15.4	23.6	214.6	15.2	23.6	214.6	15.2	23.5	214.6	-0.1	-0.1	0.0	-0.2	0.0	0.0	0.0	-0.1	0.0
AEZ16	0.3	1.5	3.1	0.3	1.5	3.1	0.3	1.5	3.1	0.3	1.5	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AEZ17	0.0	0.0	0.4	0.0	0.0	0.4	0.0	0.0	0.4	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AEZ18	0.0	0.3	0.0	0.0	0.3	0.0	0.0	0.3	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	1495.2	3322.0	1517.0	1496.2	3321.7	1519.6	1514.3	3314.9	1520.2	1528.5	3289.5	1520.2	1.0	-0.3	2.5	18.1	-6.8	0.6	14.1	-25.5	0.0

Table 2. Total area and relative changes in land cover categories for selected countries: 2004, 2007, 2011, 2014

Area (in M ha)	2004			2007			2011			2014			Diff: 2007 - 2004			Diff: 2011 - 2007			Diff: 2014 - 2011		
	Crop	Pasture	Forest	Crop	Pasture	Forest	Crop	Pasture	Forest	Crop	Pasture	Forest	Crop	Pasture	Forest	Crop	Pasture	Forest	Crop	Pasture	Forest
Australia	26.1	368.8	1.3	23.5	374.8	1.3	32.1	364.0	1.3	32.3	342.1	1.3	-2.5	6.0	0.0	8.5	-10.8	0.0	0.2	-21.9	0.0
Brazil	58.7	170.1	154.8	60.8	168.7	154.6	61.8	170.3	154.1	62.6	171.4	153.7	2.2	-1.3	-0.2	1.0	1.5	-0.5	0.7	1.1	-0.4
Canada	40.1	21.7	98.7	39.1	21.0	99.2	37.5	20.2	99.9	38.2	19.7	99.8	-1.1	-0.7	0.6	-1.6	-0.7	0.7	0.7	-0.5	-0.1
China	124.4	392.8	112.5	122.6	392.8	113.4	122.5	392.8	113.4	122.5	392.8	113.4	-1.9	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0
France	19.5	10.0	15.5	19.4	9.8	15.7	19.3	9.6	15.9	19.3	9.4	15.9	-0.1	-0.1	0.2	-0.1	-0.3	0.2	0.0	-0.2	0.1
India	169.9	10.5	16.9	169.2	10.4	17.0	169.4	10.3	17.0	169.5	10.3	17.0	-0.7	-0.1	0.1	0.2	-0.1	0.0	0.1	0.0	0.0
Indonesia	42.4	11.0	34.5	42.0	11.0	34.6	45.5	11.0	33.6	46.0	11.0	33.5	-0.4	0.0	0.1	3.5	0.0	-0.9	0.5	0.0	-0.1
Russia	124.0	92.0	249.1	123.4	92.1	249.2	123.3	93.0	249.1	123.2	93.0	249.1	-0.6	0.1	0.1	-0.1	0.9	-0.1	-0.1	0.0	0.0
USA	171.2	241.8	211.6	164.5	248.4	213.0	159.1	250.5	214.9	158.8	248.6	215.5	-6.7	6.6	1.5	-5.4	2.1	1.9	-0.3	-1.8	0.5
South Africa	13.7	83.9	1.2	13.0	83.9	1.3	12.4	83.9	1.3	12.4	83.9	1.3	-0.7	0.0	0.0	-0.5	0.0	0.0	0.0	0.0	0.0

b. Land Use

Global distribution of coarse grains, paddy rice and wheat production (left, middle and right panels) for benchmark years 2004, 2007, 2011 and 2014 are illustrated in Figure 4. Most of the world's coarse grains (left panel) are produced in the U.S. (AEZ8 to AEZ10), China (AEZ9 and AEZ10), Brazil (AEZ5 and AEZ12), Russia (AEZ8 and AEZ9) and India (AEZ3). Hotspots for global paddy rice production (middle panel) are generally concentrated in East, South and South East Asia specifically in China (AEZ11 and AEZ12), India (AEZ3 and AEZ4), Thailand (AEZ4), Vietnam (AEZ5), and Myanmar (AEZ4). Relative to the crops mentioned above, global production of wheat is more widely dispersed. Key regions wherein wheat production is high include the U.S. (AEZ8), India (AEZ8 and AEZ9), Russia (AEZ8 and AEZ9), Canada (AEZ8), France (AEZ10), Kazakhstan (AEZ8) and China (AEZ9 to AEZ11). Figure 5 shows the global distribution of harvested areas for coarse grains, paddy rice and wheat (left, middle and right panels) for benchmark years 2004, 2007, 2011 and 2014. In general, the hotspots of harvested area are in the same region-AEZs where production hotspots are also observed.

Global production and harvested area of selected GTAP crops for each benchmark year are listed in Table 3. Relative changes for benchmark periods are also summarized in the table. Except for wheat, world output for most selected crops grew during the period 2004-2007. Output of sugar cane & beet rose sharply followed by fruits & vegetables, oilseeds, paddy rice and coarse grains (around 269, 124, 56, 49 and 41 MMt). At the same time, harvest area for coarse grains and fruits & vegetables also expanded strongly (10 and 11 Mha). Both production and harvested areas grew faster during the period 2007-2011 compared to 2004-2007. Crop production rose for fruits & vegetables, sugar cane & beet, and oilseeds (at 291, 223 and 125 MMt). With significant growth in production, it is not surprising that harvested areas particularly for oilseeds and fruits & vegetables also expanded (29 and 16 Mha). Production and harvested area for key crop continued to increase over 2011 to 2014. Both output and harvested area grew rapidly for coarse grains, fruits & vegetables as well as oilseeds during this period (180, 203 and 104 MMts and 14, 15 and 21 Mha). Tables 4 and 5 summarize production and harvested areas of paddy rice, wheat and coarse grains for selected GTAP countries, respectively. Top producers of paddy rice include China and India while China and India are major wheat producers. The US and China grow most of the world's of coarse grains while major producers of oilseeds include US, Indonesia and Brazil. Looking at the periods 2004-2007, 2007-2011 and 2011-2014, steady

increases in crop production are observed for paddy rice in China, wheat in China and India, coarse grains in China as well as Oilseeds in Brazil and Indonesia.

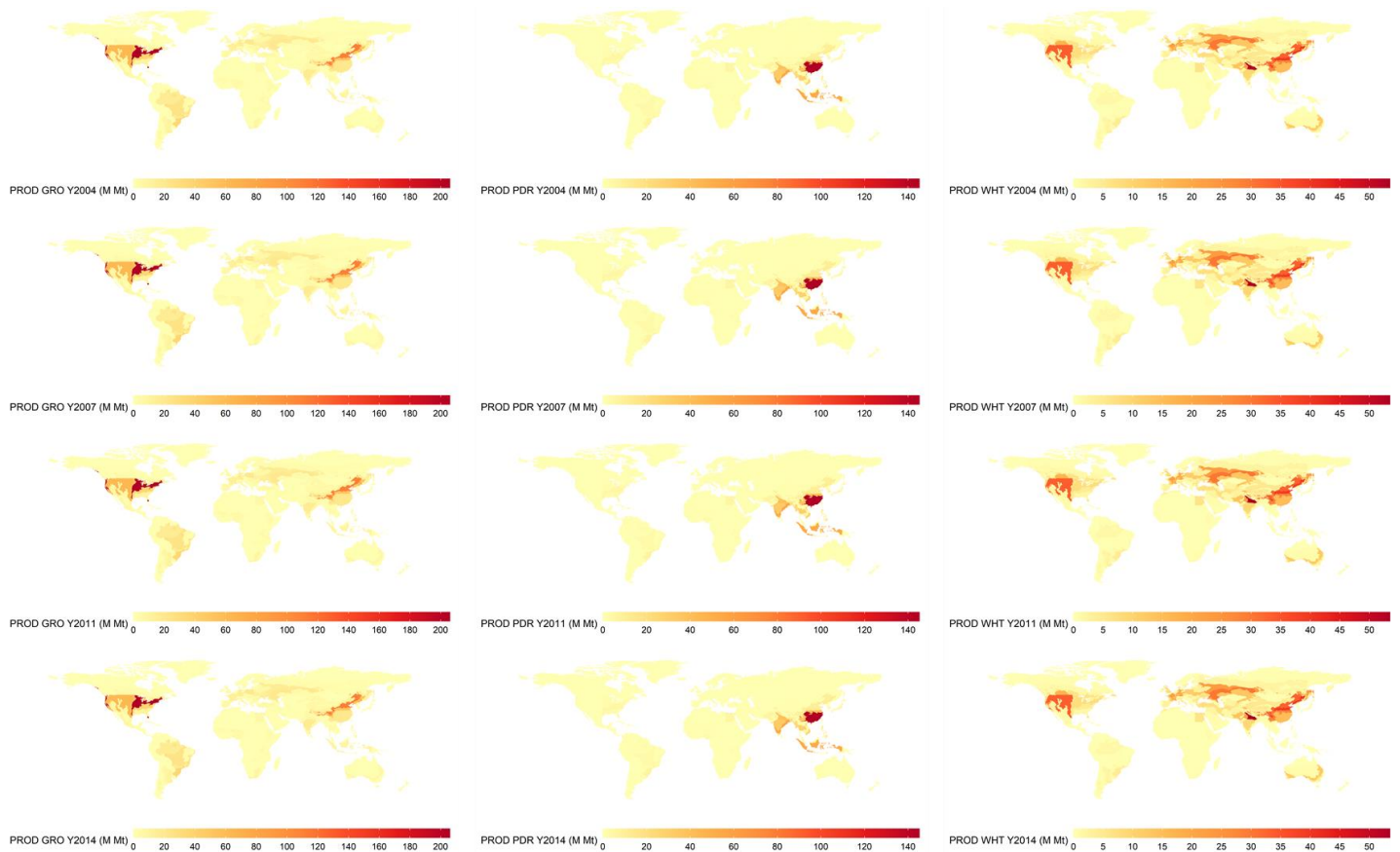


Figure 4. Production of coarse grains, paddy rice and wheat by region and AEZ: 2004 2007 2011 2014

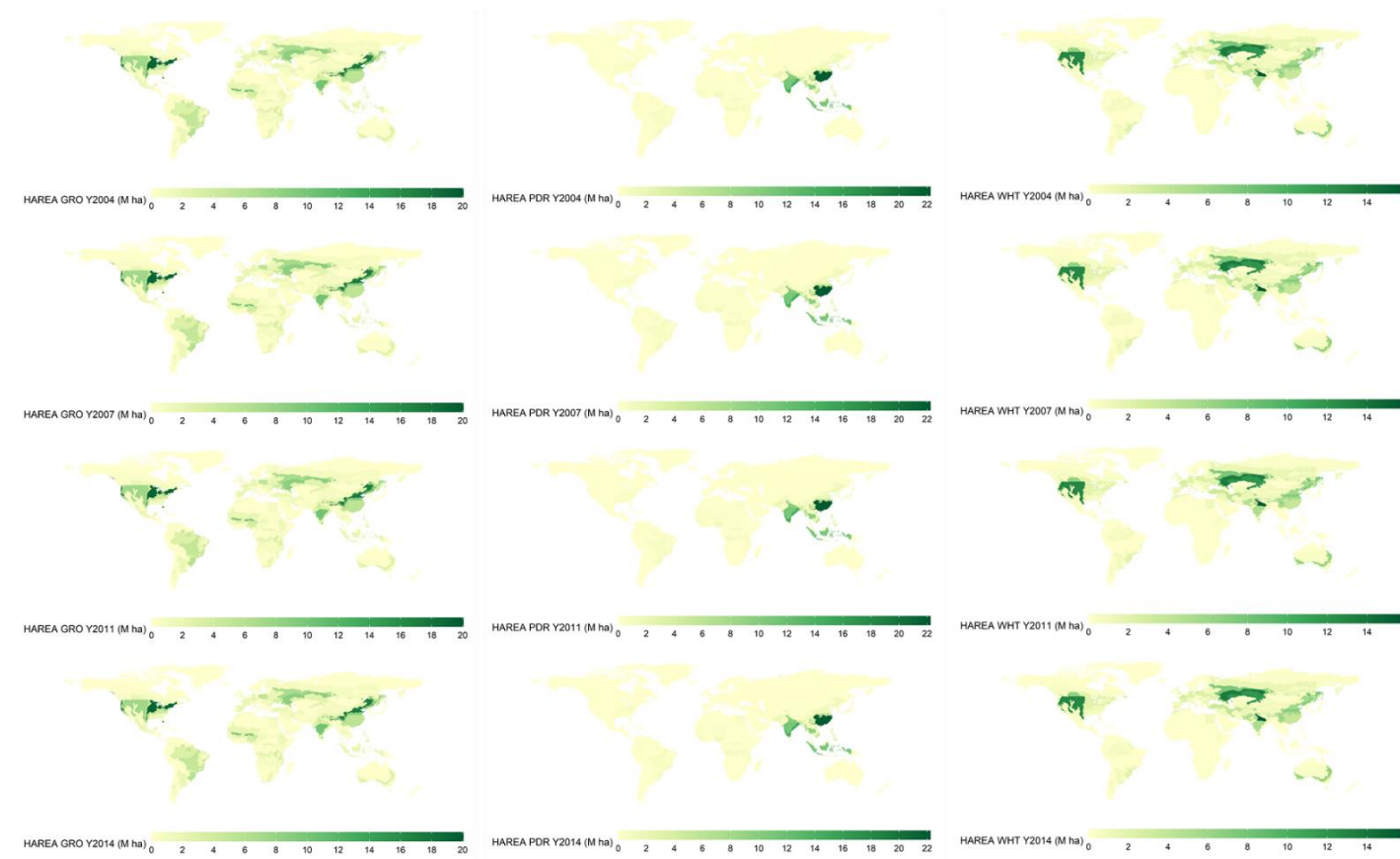


Figure 5. Harvested area of coarse grains, paddy rice and wheat by region and AEZ: 2004 2007 2011 2014

Table 3. Global production and harvested area and relative changes for selected crops: 2004, 2007, 2011, 2014

GTAP Crop Categories	Production (MMts)				Diff: 2007 -2004	Diff: 2011 -2007	Diff: 2014 -2011
	2004	2007	2011	2014			
Paddy Rice	608.7	657.9	728.0	744.1	49.2	70.1	16.1
Wheat	631.7	604.0	695.2	723.4	-27.7	91.2	28.2
Coarse Grains	1033.7	1074.3	1152.6	1332.1	40.6	78.3	179.5
Fruits and Veg.	2183.2	2307.6	2599.1	2801.9	124.4	291.4	202.8
Oilseeds	560.1	615.9	741.1	845.2	55.8	125.2	104.1
Sugar Cane & Beet	1565.1	1833.3	2056.0	2136.8	268.2	222.7	80.9
Plant Fibres	77.3	80.0	86.3	83.4	2.7	6.3	-2.9
Other Crops	47.8	49.4	57.6	61.3	1.6	8.2	3.7

GTAP Crop Categories	Harvested Area (Mha.)				Diff: 2007 -2004	Diff: 2011 -2007	Diff: 2014 -2011
	2004	2007	2011	2014			
Paddy Rice	150.9	155.5	163.0	164.4	4.6	7.4	1.4
Wheat	214.9	214.6	219.8	219.0	-0.3	5.1	-0.7
Coarse Grains	303.8	314.3	311.7	326.0	10.6	-2.7	14.4
Fruits and Veg.	231.1	242.4	258.8	273.7	11.3	16.4	14.9
Oilseeds	207.4	212.2	241.4	262.2	4.8	29.2	20.8
Sugar Cane & Beet	25.4	27.7	30.5	31.4	2.3	2.7	0.9
Plant Fibres	38.0	36.4	37.6	37.4	-1.6	1.2	-0.1
Other Crops	34.3	34.4	36.9	37.8	0.1	2.4	1.0

Table 4. Production and relative changes for selected countries and crops: 2004, 2007, 2011, 2014

Crops	Regions	Production (M Mts)				Diff: 2007 -2004	Diff: 2011 -2007	Diff: 2014 -2011
		2004	2007	2011	2014			
Paddy	Australia	0.6	0.2	0.7	0.8	-0.4	0.6	0.1
Rice	Brazil	13.3	11.1	13.5	12.2	-2.2	2.4	-1.3
	Canada	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	China	180.5	187.4	202.7	208.2	6.9	15.3	5.6
	France	0.1	0.1	0.1	0.1	0.0	0.0	0.0
	India	124.7	144.6	157.9	157.2	19.9	13.3	-0.7
	Indonesia	54.1	57.2	65.8	70.8	3.1	8.6	5.1
	Russia	0.5	0.7	1.1	1.0	0.2	0.4	0.0
	USA	10.5	9.0	8.4	10.1	-1.5	-0.6	1.7
	South Africa	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wheat	Australia	26.1	10.8	27.4	25.3	-15.3	16.6	-2.1
	Brazil	5.8	4.1	5.7	6.3	-1.7	1.6	0.6
	Canada	24.8	20.1	25.3	27.4	-4.7	5.2	2.2
	China	92.0	109.3	117.4	126.2	17.3	8.1	8.8
	France	39.7	32.8	36.0	39.0	-6.9	3.2	3.0
	India	72.2	75.8	86.9	95.8	3.7	11.1	9.0
	Indonesia	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Russia	45.4	49.4	56.2	59.7	3.9	6.9	3.5
	USA	58.7	55.8	54.4	55.1	-2.9	-1.4	0.7
	South Africa	1.7	1.9	2.0	1.8	0.2	0.1	-0.3
Coarse Grains	Australia	15.7	6.8	11.8	12.3	-8.9	5.1	0.5
	Brazil	44.9	54.3	58.4	83.0	9.4	4.2	24.5
	Canada	26.0	27.9	23.0	22.2	1.9	-4.9	-0.8
	China	140.7	161.1	201.1	224.9	20.4	40.0	23.8
	France	30.8	26.7	27.8	33.5	-4.1	1.1	5.7
	India	33.0	40.1	43.1	43.0	7.1	3.0	-0.1
	Indonesia	11.2	13.3	17.6	19.0	2.1	4.4	1.4
	Russia	30.1	30.1	34.5	42.4	0.1	4.4	7.9
	USA	319.8	350.3	322.7	377.6	30.5	-27.6	54.9
	South Africa	10.3	7.6	10.9	14.9	-2.7	3.3	3.9
Oilseeds	Australia	1.9	0.7	2.6	4.0	-1.2	1.9	1.5
	Brazil	54.1	62.3	79.7	91.8	8.2	17.4	12.1
	Canada	11.6	13.2	19.6	23.6	1.6	6.4	4.0
	China	50.3	41.0	50.4	50.6	-9.4	9.5	0.1
	France	5.7	6.2	7.5	7.5	0.5	1.3	0.0
	India	31.4	42.3	41.7	40.2	10.9	-0.6	-1.5
	Indonesia	78.9	99.6	124.3	159.3	20.7	24.7	35.0
	Russia	5.7	7.0	12.2	12.9	1.3	5.2	0.6
	USA	89.0	76.9	87.9	111.7	-12.1	11.0	23.9
	South Africa	1.0	0.6	1.7	2.0	-0.4	1.1	0.3

Table 5. Harvested area and relative changes for selected countries and crops: 2004, 2007, 2011, 2014

Crops	Regions	Harvested Area (M Mha)				Diff: 2007 -2004	Diff: 2011 -2007	Diff: 2014 -2011
		2004	2007	2011	2014			
Paddy	Australia	0.1	0.0	0.1	0.1	0.0	0.1	0.0
Rice	Brazil	3.7	2.9	2.8	2.3	-0.8	-0.1	-0.4
	Canada	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	China	28.6	29.2	30.3	30.6	0.6	1.1	0.3
	France	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	India	41.9	43.9	44.0	44.1	2.0	0.1	0.1
	Indonesia	11.9	12.1	13.2	13.8	0.2	1.1	0.6
	Russia	0.1	0.2	0.2	0.2	0.0	0.1	0.0
	USA	1.3	1.1	1.1	1.2	-0.2	-0.1	0.1
	South Africa	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wheat	Australia	13.1	11.8	13.5	12.6	-1.3	1.7	-0.9
	Brazil	2.8	1.9	2.1	2.8	-1.0	0.3	0.7
	Canada	9.4	8.6	8.6	9.5	-0.8	-0.1	0.9
	China	21.6	23.7	24.3	24.1	2.1	0.6	-0.2
	France	5.2	5.2	5.4	5.3	0.0	0.2	-0.1
	India	26.6	28.0	29.1	30.5	1.4	1.1	1.4
	Indonesia	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Russia	22.9	23.5	24.8	23.9	0.6	1.3	-0.9
	USA	20.2	20.6	18.5	18.8	0.4	-2.1	0.3
	South Africa	0.8	0.6	0.6	0.5	-0.2	0.0	-0.1
Coarse Grains	Australia	6.9	6.3	5.5	5.3	-0.6	-0.8	-0.2
	Brazil	13.9	14.8	14.3	16.7	0.9	-0.5	2.4
	Canada	6.8	7.5	5.0	4.5	0.8	-2.5	-0.4
	China	29.4	33.2	36.7	40.3	3.8	3.5	3.6
	France	4.1	3.9	3.8	4.3	-0.3	-0.1	0.5
	India	29.3	28.9	27.5	25.4	-0.4	-1.4	-2.1
	Indonesia	3.4	3.6	3.9	3.8	0.3	0.2	0.0
	Russia	17.4	16.7	15.6	18.1	-0.8	-1.1	2.5
	USA	35.2	40.2	37.1	38.0	5.0	-3.1	0.9
	South Africa	3.5	2.8	2.6	2.9	-0.7	-0.2	0.3
Oilseeds	Australia	1.3	1.1	2.2	2.8	-0.2	1.1	0.6
	Brazil	22.3	21.4	24.8	31.0	-0.9	3.4	6.3
	Canada	6.9	8.3	9.6	11.4	1.4	1.3	1.9
	China	24.2	20.4	22.0	21.1	-3.8	1.6	-1.0
	France	1.8	2.2	2.4	2.3	0.4	0.2	-0.1
	India	27.5	29.5	29.1	28.5	2.0	-0.5	-0.5
	Indonesia	7.3	8.6	10.3	12.3	1.3	1.7	2.0
	Russia	5.7	6.3	9.9	10.4	0.7	3.5	0.5
	USA	31.8	28.0	31.4	35.4	-3.9	3.5	4.0
	South Africa	0.8	0.6	1.2	1.3	-0.2	0.6	0.1

c. Land Rents

With the geospatial land use and land cover at hand, the land rents in the original GTAP v.10 data for agricultural, livestock and forestry sectors are then shared out for each region-AEZ. Figure 6 shows the value of land endowments (EVOA) by region-AEZ for each benchmark year. Value of land endowments are highest in China (AEZ9 to AEZ12), Saudi Arabia (AEZ7), India (AEZ3, AEZ4 and AEZ9), Russia (AEZ8 and AEZ9) the U.S. (AEZ 10) and Canada (AEZ10). Summing EVOA across all regions, Table 6 shows the value of land endowments by AEZ. More than half of the land rents are concentrated in AEZ9 to AEZ12. Looking at changes across benchmark years, the growth in land rents remains strong for periods 2004-2007 and 2007-2011 while in the increase is relatively smaller in 2011-2014 compared to previous periods. Most of the rise in land rents are concentrated in AEZ4, AEZ5, AEZ9 to AEZ10.

Figure 7 shows the producer expenditure on land endowments (EVFA) by the coarse grain, paddy rice and wheat sectors (left, middle and right panels) for each region-AEZ in 2004, 2007, 2011 and 2014. Note that the distribution of EVFA is based on the distribution of crop production so it is not surprising Figure 7 mirrors the distribution in Figure 4. Expenditures on land endowments by the agricultural, livestock and forestry sector are summarized in Table 7. Among the agricultural sectors, expenditures on land inputs is highest for fruits and vegetables followed by paddy rice. More than half of the purchases of land by the livestock sector is generated by the raw milk sector. Key crop sectors which consistently increased their spending in land inputs coarse grains, oilseeds and paddy rice.

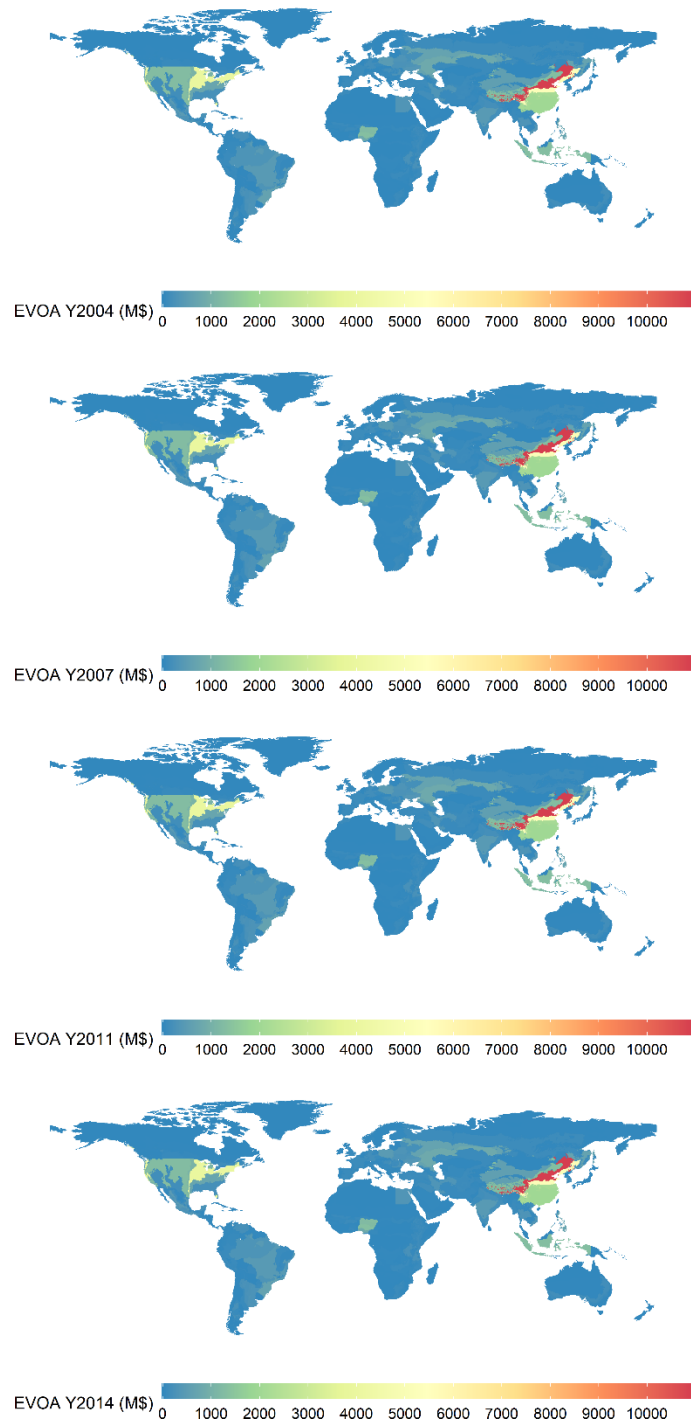


Figure 6. Value of land endowments at agent's prices (EVOA) by region and AEZ: 2004 2007 2011 2014

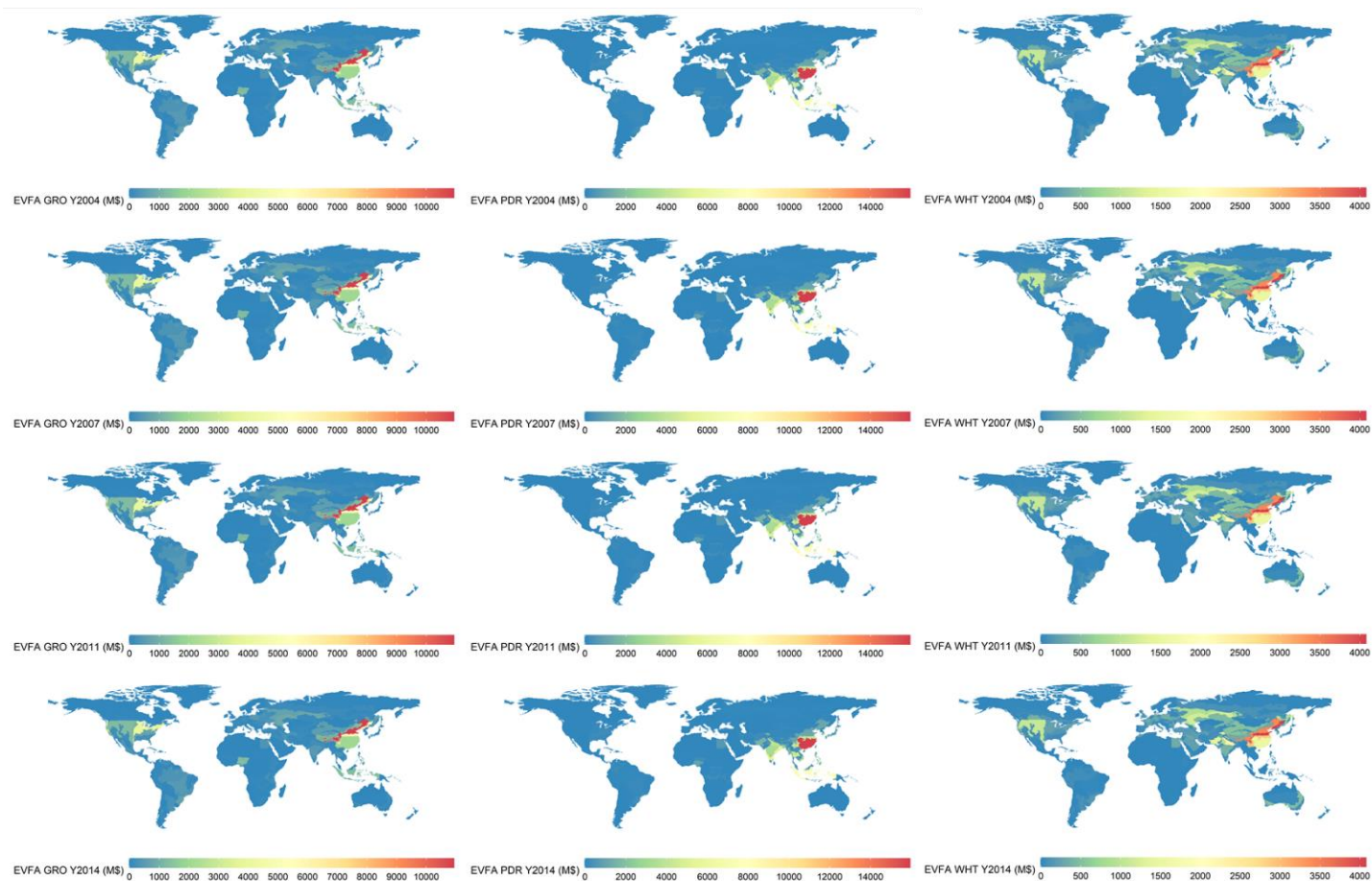


Figure 7. Value of producer expenditure on land inputs at agent's prices of coarse grains, paddy rice and wheat by region and AEZ: 2004 2007 2011 2014

Table 6. Value of land endowments at agent's prices in M USD: 2004, 2007, 2011, 2014

EVOA (in M USD)	2004	2007	2011	2014	Diff: 2007 -2004	Diff: 2011 -2007	Diff: 2014 -2011
AEZ1	1036.9	1722.3	2354.6	2891.8	685.4	632.3	537.2
AEZ2	2874.1	6401.1	9153.7	10433.1	3527.1	2752.6	1279.3
AEZ3	11371.4	26683.5	32931.7	35752.9	15312.1	6248.2	2821.2
AEZ4	20818.4	39545.1	65765.2	70565.4	18726.8	26220.0	4800.2
AEZ5	17823.3	30326.5	50631.9	60654.4	12503.3	20305.3	10022.5
AEZ6	23604.3	43283.4	62635.0	66213.6	19679.2	19351.5	3578.7
AEZ7	10566.2	19083.3	29540.3	36375.8	8517.1	10456.9	6835.5
AEZ8	19191.7	38047.2	47119.0	53123.0	18855.5	9071.8	6003.9
AEZ9	37642.2	66660.3	86439.6	94807.3	29018.0	19779.3	8367.6
AEZ10	70896.6	91284.6	106361.0	131917.9	20387.9	15076.5	25556.8
AEZ11	56598.5	59064.1	71802.5	71624.7	2465.6	12738.5	-177.9
AEZ12	35035.8	56450.6	75454.3	77944.5	21414.8	19003.7	2490.1
AEZ13	870.1	1019.5	1975.5	2650.8	149.4	956.0	675.4
AEZ14	4903.3	5841.1	7569.8	8055.2	937.8	1728.7	485.4
AEZ15	8541.2	12590.6	12482.4	14129.4	4049.3	-108.2	1647.0
AEZ16	442.7	653.4	698.7	707.0	210.7	45.3	8.3
AEZ17	16.3	23.2	31.3	34.0	6.9	8.1	2.7
AEZ18	7.6	15.6	21.1	27.4	8.0	5.5	6.3

Table 7. Value of producer expenditure on land endowments at agent's prices in M USD: 2004, 2007, 2011, 2014

EVFA (in M USD)	2004	2007	2011	2014	Diff: 2007 - 2004	Diff: 2011 - 2007	Diff: 2014 - 2011
Paddy Rice	34094.1	39619.0	83665.3	87697.3	5524.9	44046.3	4032.0
Wheat	11502.6	22152.8	30166.2	36287.4	10650.2	8013.3	6121.2
Coarse Grains	17064.2	32827.6	49621.0	59086.3	15763.3	16793.4	9465.4
Fruits and Veg.	57094.4	157494.1	135034.1	144998.7	100399.7	-22460.0	9964.6
Oilseeds	16497.2	30423.7	45085.3	59618.8	13926.5	14661.6	14533.5
Sugar Cane & Beet	6358.7	9978.2	20644.8	18513.6	3619.5	10666.5	-2131.2
Plant Fibres	6148.8	12761.6	18873.1	19738.3	6612.8	6111.5	865.2
Other Crops	25724.8	44342.2	53206.9	49665.3	18617.4	8864.7	-3541.7
Cattle, sheep, goats, horses	17474.7	28421.2	44848.2	53708.6	10946.6	16427.0	8860.4
Raw milk	24059.1	43543.3	51696.0	58608.2	19484.2	8152.7	6912.2
Wool, silk-worm cocoons	1643.5	2724.2	3670.2	7992.4	1080.7	946.0	4322.2
Forestry	64124.1	80738.6	114365.5	131765.7	16614.5	33626.9	17400.3

d. Comparing land cover, land use and land rents in v.9 and v.10

To see key differences in land cover, land use and land rents, v.9 is compared with v.10 for benchmark years 2004, 2007 and 2011 data. Difference in cropland, pasture and forest cover by AEZ are highlighted in Figure 8 (top, middle and bottom panels). In general, there are little difference between v.9 and v.10 in terms of cropland, pastureland and forestry cover for each benchmark year. This is expected since v.10 uses the same data sources and workflow as v.9. Minor differences are mainly attributed to differences in FAOSTAT data (FAOSTAT data used in v.9 was downloaded on 2017). There are also minor differences in the patterns of crop production and harvested area in v.9 and in v.10. Figures 9 and 10 shows the production and harvested area of coarse grains, paddy rice and wheat (top, middle and bottom panels) for years 2004, 2007 and 2011 by AEZ.

Figures 11 and 12 shows the differences in the computed land rents for v.9 and v.10. Figure 11 shows the value of land endowments (EVOA) in B USD and as % of global value (top and bottom panels) for years 2004, 2007, 2011 by AEZ. Looking at the values (top panel), EVOA in each AEZ are different between v.9 and v.10 due to differences GTAP base data versions. These differences persists even in % shares (bottom panel) particularly in AEZ7, AEZ10 and AEZ11. Value of producer expenditure on land inputs at agent's prices (EVFA) by the agriculture, livestock and forestry sectors in each AEZ are illustrated in Figure 12. Here, the expenditure of land inputs in the agriculture and livestock sectors are quite different from v.9 and v.10.

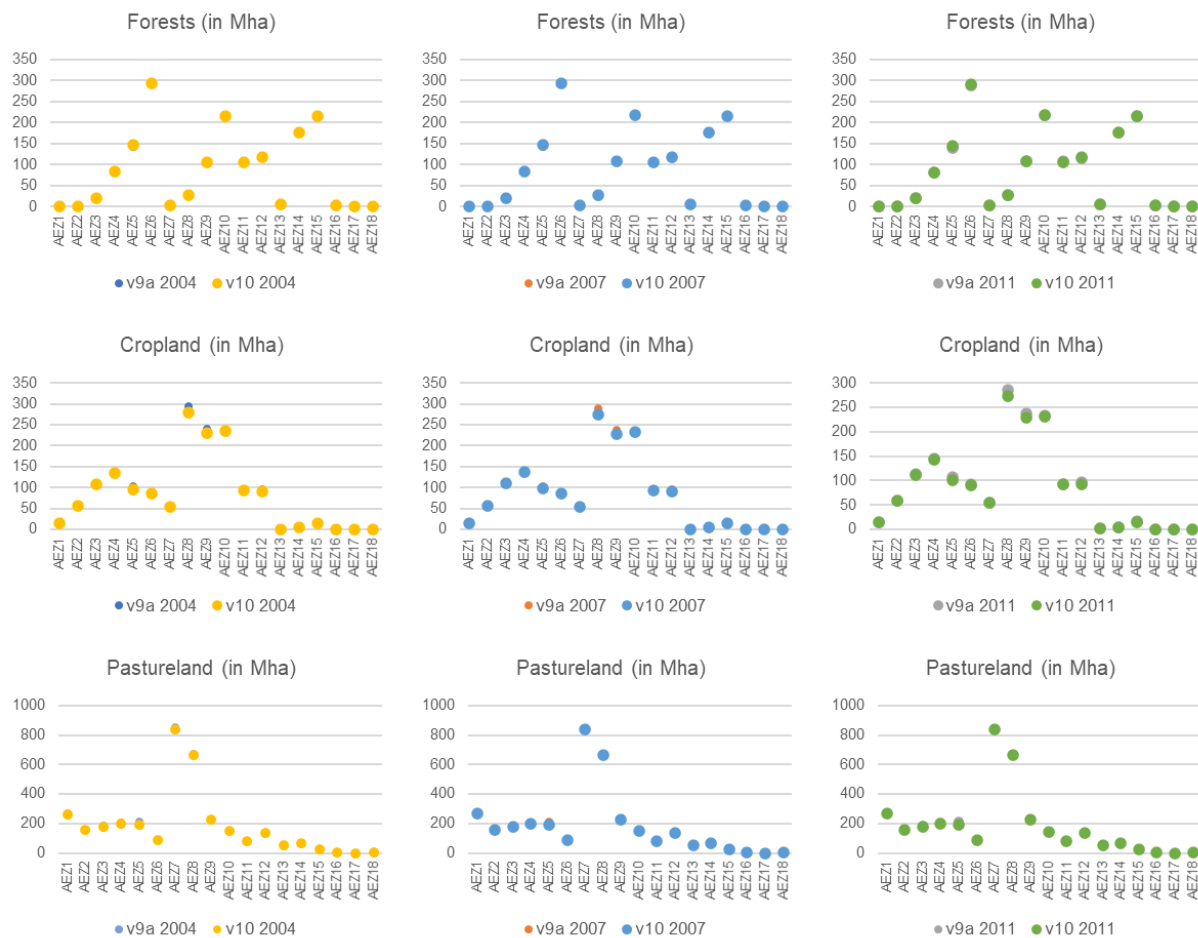


Figure 8. Cropland, pasture and forest land cover by AEZ: 2004 2007 2011

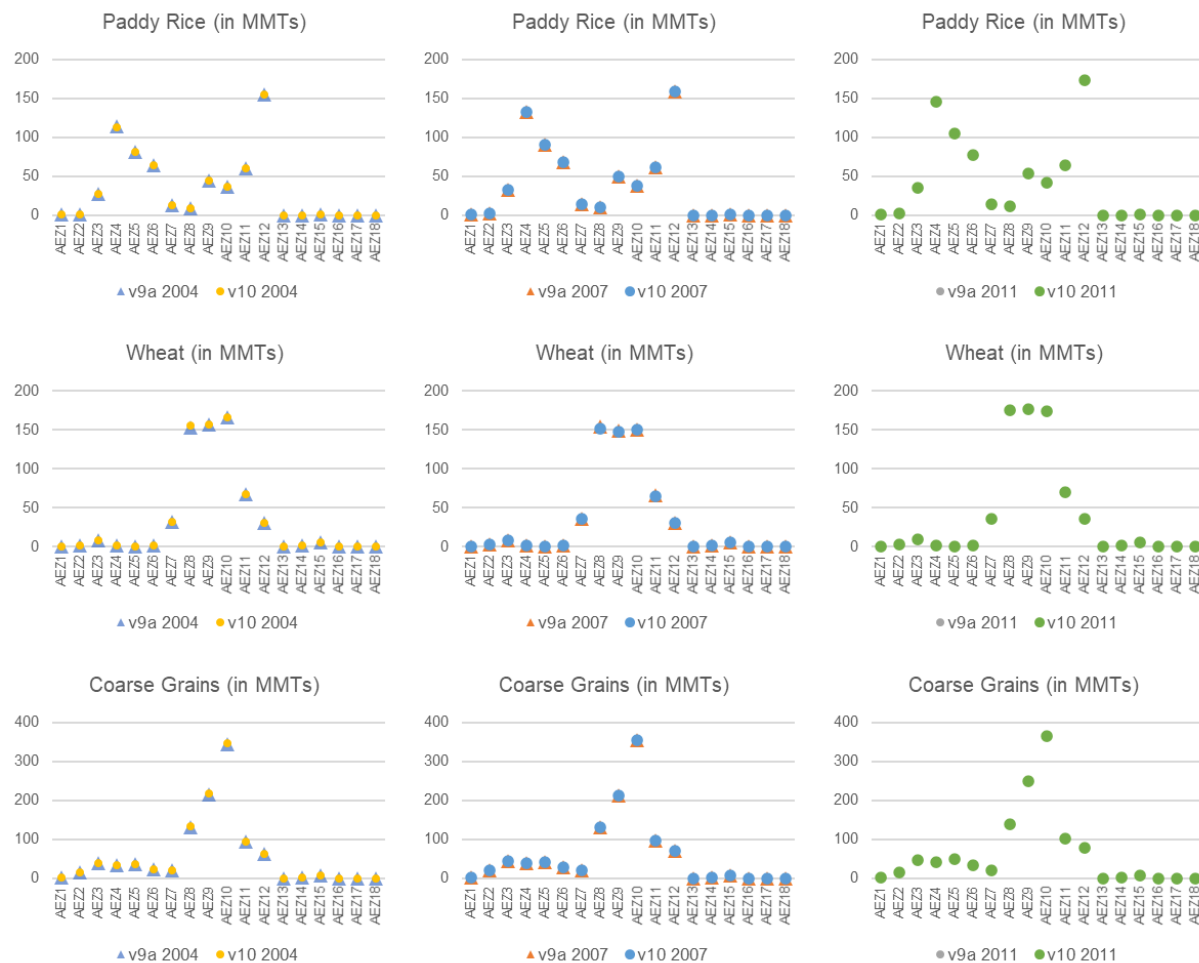


Figure 9. Production of paddy rice, wheat and coarse grains by AEZ: 2004 2007 2011

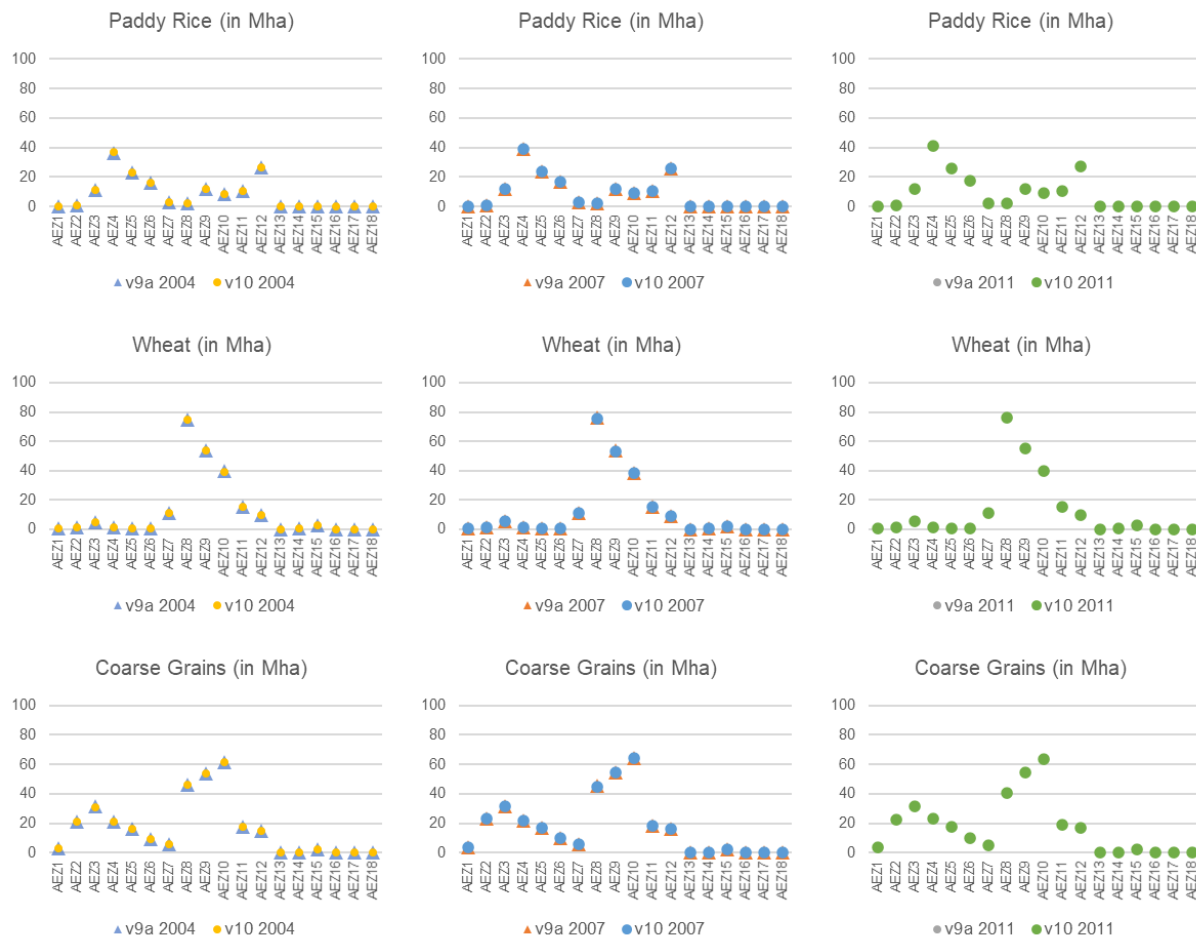


Figure 10. Harvested area of paddy rice, wheat and coarse grains by AEZ: 2004 2007 2011

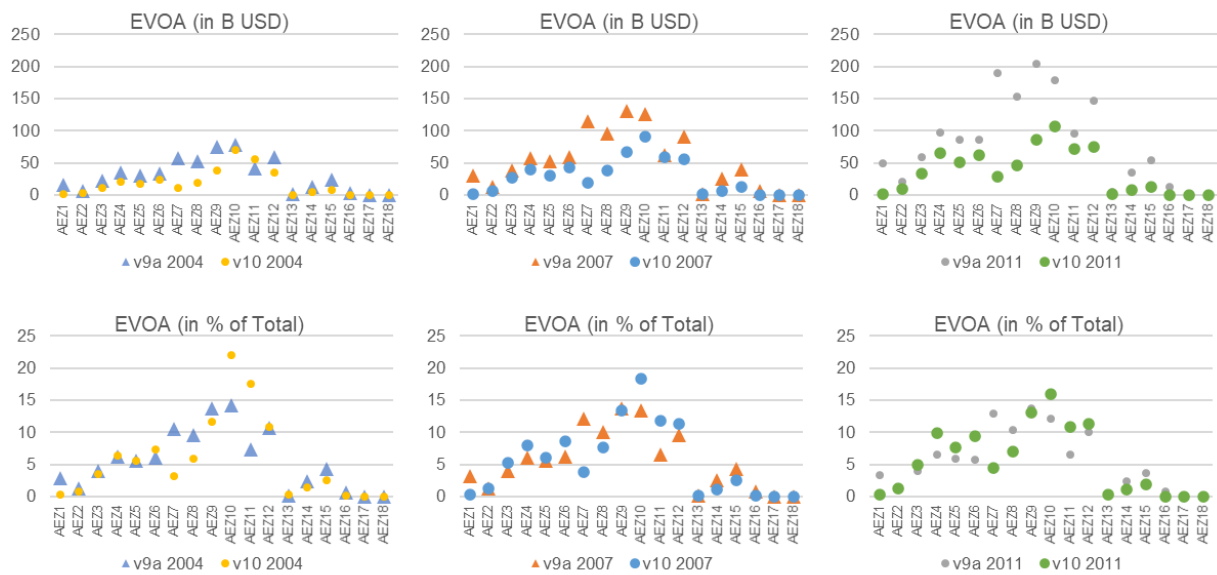


Figure 11. Value of land endowments at agent's prices (EVOA) in B USD and in % global share by AEZ: 2004 2007 2011 2014

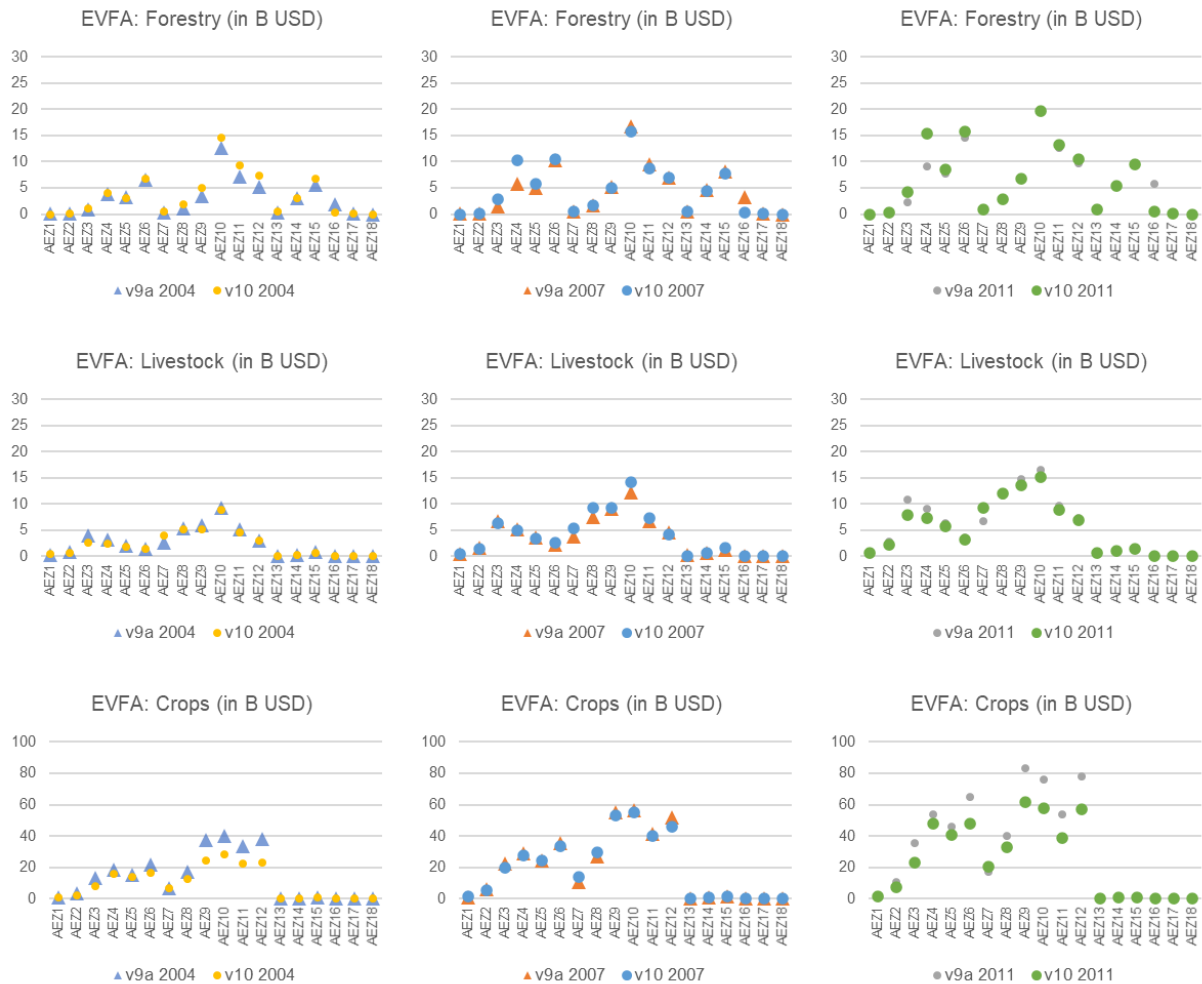


Figure 12. Value of producer expenditure on land inputs at agent's prices (EVFA) of forestry, livestock and crops sectors by AEZ: 2004 2007 2011

III. Summary and conclusion

GTAP LULCv.10 is created directly from publicly available high-resolution (i.e. 5-minute) spatial land cover and land use maps combined with the latest national data from FAOSTAT (2020) and GTAP database version 10. With better capacity to handle spatial data within the Center, future versions of the GTAP LULC can immediately incorporate new geospatial information allowing us to have a better understanding of the tensions and trade-offs in the land-environment-energy nexus. In the future, new versions of the upcoming land use and land cover database will be immediately incorporated when latest land use and land cover maps become available (e.g. GAEZ version 4.0). We will also mainstream the creation of the GTAP LULC database allowing us to create this database immediately as soon as new GTAP base data versions are available. Finally, we also plan to make change to the main version of the GTAP AEZ model to incorporate volume preserving land use (CET and/or CRETH) functions and explore the implementation of the AEZ framework in the recursive dynamic version of GTAP.

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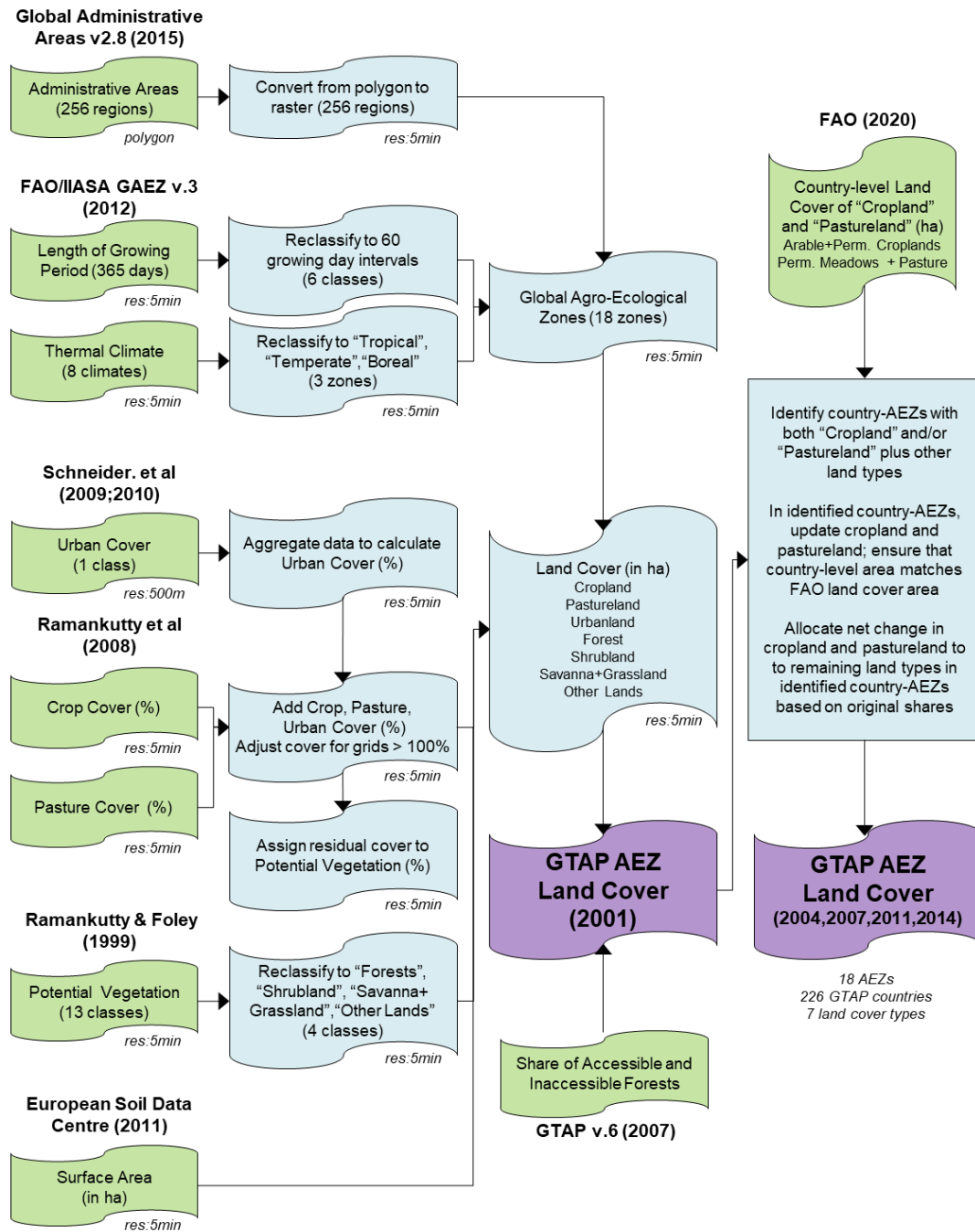
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Appendices

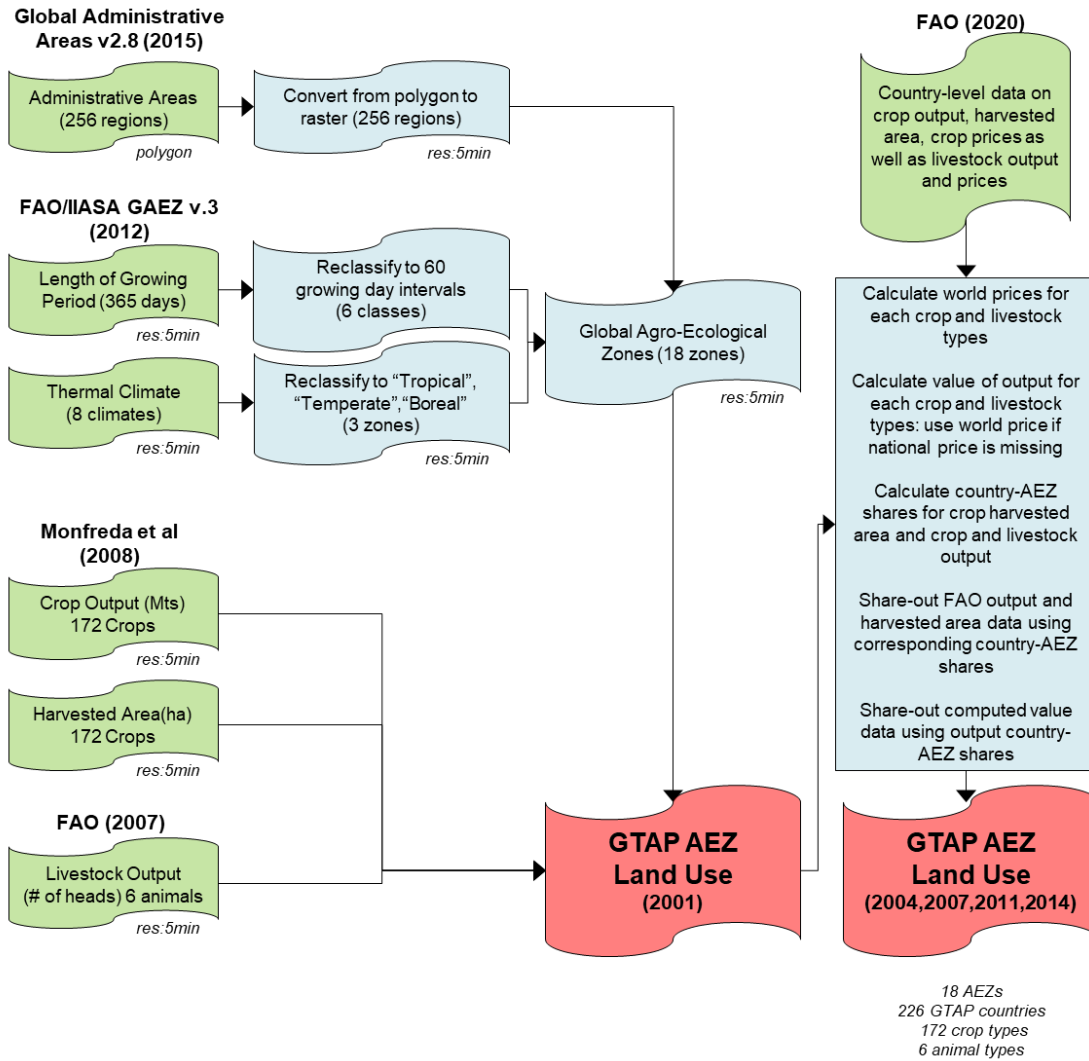
Appendix I. Data and Methods for GTAP LULC v.10

Figure 1 and 2 summarize the data and methods used in creating and updating the land cover and land use information in the GTAP LULCv.10 database, respectively. As noted above, data sources and methods used in GTAP LULCv.10 are the same as in GTAP LULCv.9 (Baldos, 2017). At the core of the GTAP LULC v.10 database are fine-resolution (5-minute) geospatial maps on administrative areas, growing conditions, land cover and land use. Each workflow starts with the creation of Global Agro-Ecological Zone (GAEZ) map which contains both administrative and agro-ecological zone information. Administrative boundaries are taken from the Global Administrative Areas map v2.8 (2016) which contains information on the boundaries of 256 countries. These are mapped to the 226 GTAP countries and GTAP regions for v.10 (see Appendix II). Each 5-minute grid-cell of the Earth's land area is classified according to agro-ecological zones (AEZs) (see Appendix III and Appendix IV). AEZ categories are created using information on length of growing period (LGP) and thermal climate from the latest information from FAO/IIASA GAEZ v.3 (2012). The LPG shows the number of days in a year when the prevailing temperature and available moisture permit crop growth (i.e. days wherein average daily temperature is above 5°C and actual evapotranspiration is above the threshold level of 0.5). On the other hand, the thermal climates broadly classify each grid-cell according to tropics, subtropics, temperate, boreal and arctic climates (IIASA/FAO, 2012). The original thermal climates (8 types) are reclassified to 3 zones (Tropical, Temperate and Boreal).

With the GAEZ map on hand, Appendix Figure I.1 further shows how information from different land cover maps are combined into the GTAP LULC database. Fractional cropland and pasture cover maps for year 2000/01 developed by Ramankutty et al (2008) (downloadable from <http://www.earthstat.org/>) is combined with the fractional urban cover information created from urban cover maps by Schneider et al (2009, 2010). Fractional cropland, pasture and urban land information are then added together in each grid cells. To ensure that total fractional land cover do not exceed 100%, fractional land cover data are normalized for grid cells which exceed the said threshold. For each grid cell, the residual fractional land cover (taken from the difference between 100% and the combined fractional cropland, pasture and urban cover) are reassigned to



Appendix Figure I.1. Workflow for creating GTAP LULCv10 land cover data for years 2004, 2007, 2011 and 2014



Appendix Figure I.2. Workflow for creating GTAP LULCv10 land use data for years 2004, 2007, 2011 and 2014

vegetation classes using the potential vegetation map developed by Ramankutty and Foley (1999). The authors assigned each grid cell of the world to one of 13 potential vegetation classes. These classes are further reclassified into 4 land types (namely Forests, Shrubland, Savanna + Grasslands and Other Lands). The complete fractional land cover maps are converted to hectares using 5-minute surface area map from the European Soil Data Center (2012). To separate accessible¹ and inaccessible forest cover, the region-18AEZ shares computed by Sohngen et al (2008) for GTAP LULC v.6 are used. The resulting land cover database from the data and methods mentioned above is for base year 2001, 140 regions, 7 land cover types and for 18 AEZs.

Currently, there are no available maps which have more recent land cover (as well as land use) information. So in order to update the new 2001 base year land cover database for each benchmark years (i.e. 2004, 2007, 2011) national level data from FAOSTAT (FAO, 2020) is used. Cropland and pasturelands are first updated using national-level land cover for these land types for each benchmark year. Thus, cropland and pastureland area between FAO and GTAP LULC at the national-level are the same. Note that land cover is updated only in region-AEZ wherein both cropland, pasture and other land types are present (if this condition is not met, land cover in a region-AEZ is fixed to the 2001 base year values). For each region-AEZ that is updated, the net change in cropland and pasture are allocated to other land types using their original shares in the base year 2001.

Figure 2 shows the workflow of the land use data for GTAP LULC v.10. Starting with the GAEZ map, the gridded production and harvested area for 172² crops from Monfreda et al. (2008) are used. Unlike previous versions which use representative crops to share-out livestock land rents, v.10 uses gridded livestock (6 types) output from FAO (2007). National level prices from FAOSTAT (2020) are used to calculate the value of crop and livestock production. Once output, harvest area and value of output data are constructed for base year 2001, region-AEZ shares for these variables are created. These shares are then used to share-out national level output, harvest area and value of output data information from FAOSTAT (2020) for the benchmark years (Appendix V).

¹ Accessible forest area includes forests with land rents such as managed forest and unmanaged forest which are easily accessible.

² The original Monfreda et al database is for 175 crops but at the time of creating the database production and harvested area for minor commodities (popcorn, coir, gums) were not available.

Appendix II. Country mapping

GTAP	GTAP226	GTAP140	GTAP141	GADM	FAO NAMES
1	abw	XCB	XCB	ABW	Aruba
2	afg	XSA	XSA	AFG	Afghanistan
3	ago	XAC	XAC	AGO	Angola
4	aia	XCB	XCB	----	----
5	alb	ALB	ALB	ALB	Albania
6	and	XER	XER	AND	Andorra
7	ant	XCB	XCB	----	----
8	are	ARE	ARE	ARE	United Arab Emirates
9	arg	ARG	ARG	ARG	Argentina
10	arm	ARM	ARM	ARM	Armenia
11	asm	XOC	XOC	ASM	American Samoa
12	atg	XCB	XCB	ATG	Antigua and Barbuda
13	aus	AUS	AUS	AUS	Australia
14	aut	AUT	AUT	AUT	Austria
15	aze	AZE	AZE	AZE	Azerbaijan
16	bdi	XEC	XEC	BDI	Burundi
17	bel	BEL	BEL	BEL	Belgium
18	ben	BEN	BEN	BEN	Benin
19	bfa	BFA	BFA	BFA	Burkina Faso
20	bgd	BGD	BGD	BGD	Bangladesh
21	bgr	BGR	BGR	BGR	Bulgaria
22	bhr	BHR	BHR	BHR	Bahrain
23	bhs	XCB	XCB	BHS	Bahamas
24	bih	XER	XER	BIH	Bosnia and Herzegovina
25	blr	BLR	BLR	BLR	Belarus
26	blz	XCA	XCA	BLZ	Belize
27	bmu	XNA	XNA	BMU	Bermuda
28	bol	BOL	BOL	BOL	Bolivia (Plurinational State of)
29	bra	BRA	BRA	BRA	Brazil
30	brb	XCB	XCB	BRB	Barbados
31	brn	BRN	BRN	BRN	Brunei Darussalam
32	btn	XSA	XSA	BTN	Bhutan
33	bwa	BWA	BWA	BWA	Botswana
34	caf	XCF	XCF	CAF	Central African Republic
35	can	CAN	CAN	CAN	Canada
36	che	CHE	CHE	CHE	Switzerland
37	chl	CHL	CHL	CHL	Chile
38	chn	CHN	CHN	CHN	China
39	civ	CIV	CIV	CIV	Côte d'Ivoire
40	cmr	CMR	CMR	CMR	Cameroon
41	cod	XAC	XAC	COD	Democratic Republic of the Congo
42	cog	XCF	XCF	COG	Congo
43	cok	XOC	XOC	COK	Cook Islands
44	col	COL	COL	COL	Colombia
45	com	XEC	XEC	COM	Comoros
46	cpv	XWF	XWF	CPV	Cabo Verde
47	cri	CRI	CRI	CRI	Costa Rica
48	cub	XCB	XCB	CUB	Cuba
49	cym	XCB	XCB	CYM	Cayman Islands
50	cyp	CYP	CYP	CYP	Cyprus
51	cze	CZE	CZE	CZE	Czechia
52	deu	DEU	DEU	DEU	Germany
53	dji	XEC	XEC	DJI	Djibouti
54	dma	XCB	XCB	DMA	Dominica
55	dnk	DNK	DNK	DNK	Denmark
56	dom	DOM	DOM	DOM	Dominican Republic
57	dza	XNF	XNF	DZA	Algeria
58	ecu	ECU	ECU	ECU	Ecuador
59	egy	EGY	EGY	EGY	Egypt
60	eri	XEC	XEC	ERI	Eritrea
61	esp	ESP	ESP	ESP	Spain
62	est	EST	EST	EST	Estonia
63	eth	ETH	ETH	ETH	Ethiopia
64	fin	FIN	FIN	FIN	Finland
65	fji	XOC	XOC	FJI	Fiji

66	flk	XSM	XSM	FLK	Falkland Islands (Malvinas)
67	fra	FRA	FRA	FRA	France
68	fro	XER	XER	FRO	Faroe Islands
69	fsm	XOC	XOC	FSM	Micronesia (Federated States of)
70	gab	XCF	XCF	GAB	Gabon
71	gbr	GBR	GBR	GBR	United Kingdom
72	geo	GEO	GEO	GEO	Georgia
73	gha	GHA	GHA	GHA	Ghana
74	gib	XER	XER	----	----
75	gin	GIN	GIN	GIN	Guinea
76	glp	FRA	FRA	GLP	Guadeloupe
77	gmb	XWF	XWF	GMB	Gambia
78	gnb	XWF	XWF	GNB	Guinea-Bissau
79	gnq	XCF	XCF	GNQ	Equatorial Guinea
80	grc	GRC	GRC	GRC	Greece
81	grd	XCB	XCB	GRD	Grenada
82	grl	XNA	XNA	GRL	Greenland
83	gtm	GTM	GTM	GTM	Guatemala
84	guf	XSM	XSM	GUF	French Guiana
85	gum	XOC	XOC	GUM	Guam
86	guy	XSM	XSM	GUY	Guyana
87	hkg	HKG	HKG	HKG	China, Hong Kong SAR
88	hnd	HND	HND	HND	Honduras
89	hrv	HRV	HRV	HRV	Croatia
90	hti	XCB	XCB	HTI	Haiti
91	hun	HUN	HUN	HUN	Hungary
92	idn	IDN	IDN	IDN	Indonesia
93	ind	IND	IND	IND	India
94	irl	IRL	IRL	IRL	Ireland
95	irn	IRN	IRN	IRN	Iran (Islamic Republic of)
96	irq	XWS	XWS	IRQ	Iraq
97	isl	XEF	XEF	ISL	Iceland
98	isr	ISR	ISR	ISR	Israel
99	ita	ITA	ITA	ITA	Italy
100	jam	JAM	JAM	JAM	Jamaica
101	jor	JOR	JOR	JOR	Jordan
102	jpn	JPN	JPN	JPN	Japan
103	kaz	KAZ	KAZ	KAZ	Kazakhstan
104	ken	KEN	KEN	KEN	Kenya
105	kgz	KGZ	KGZ	KGZ	Kyrgyzstan
106	khm	KHM	KHM	KHM	Cambodia
107	kir	XOC	XOC	KIR	Kiribati
108	kna	XCB	XCB	KNA	Saint Kitts and Nevis
109	kor	KOR	KOR	KOR	Republic of Korea
110	kwf	KWT	KWT	KWT	Kuwait
111	lao	LAO	LAO	LAO	Lao People's Democratic Republic
112	lbn	XWS	XWS	LBN	Lebanon
113	lbr	XWF	XWF	LBR	Liberia
114	lby	XNF	XNF	LBY	Libya
115	lca	XCB	XCB	LCA	Saint Lucia
116	lie	XEF	XEF	LIE	Liechtenstein
117	lka	LKA	LKA	LKA	Sri Lanka
118	lso	XSC	XSC	LSO	Lesotho
119	ltu	LTU	LTU	LTU	Lithuania
120	lux	LUX	LUX	LUX	Luxembourg
121	lva	LVA	LVA	LVA	Latvia
122	mac	XEA	XEA	----	----
123	mar	MAR	MAR	MAR	Morocco
124	mco	XER	XER	MCO	Mexico
125	mda	XEE	XEE	MDA	Republic of Moldova
126	mdg	MDG	MDG	MDG	Madagascar
127	mdv	XSA	XSA	MDV	Maldives
128	mex	MEX	MEX	MEX	Mexico
129	mhl	XOC	XOC	MHL	Marshall Islands
130	mkd	XER	XER	MKD	The former Yugoslav Republic of Macedonia
131	mli	XWF	XWF	MLI	Mali
132	mlt	MLT	MLT	MLT	Malta
133	mmr	XSE	XSE	MMR	Myanmar
134	mng	MNG	MNG	MNG	Mongolia
135	mnp	XOC	XOC	MNP	Northern Mariana Islands
136	moz	MOZ	MOZ	MOZ	Mozambique

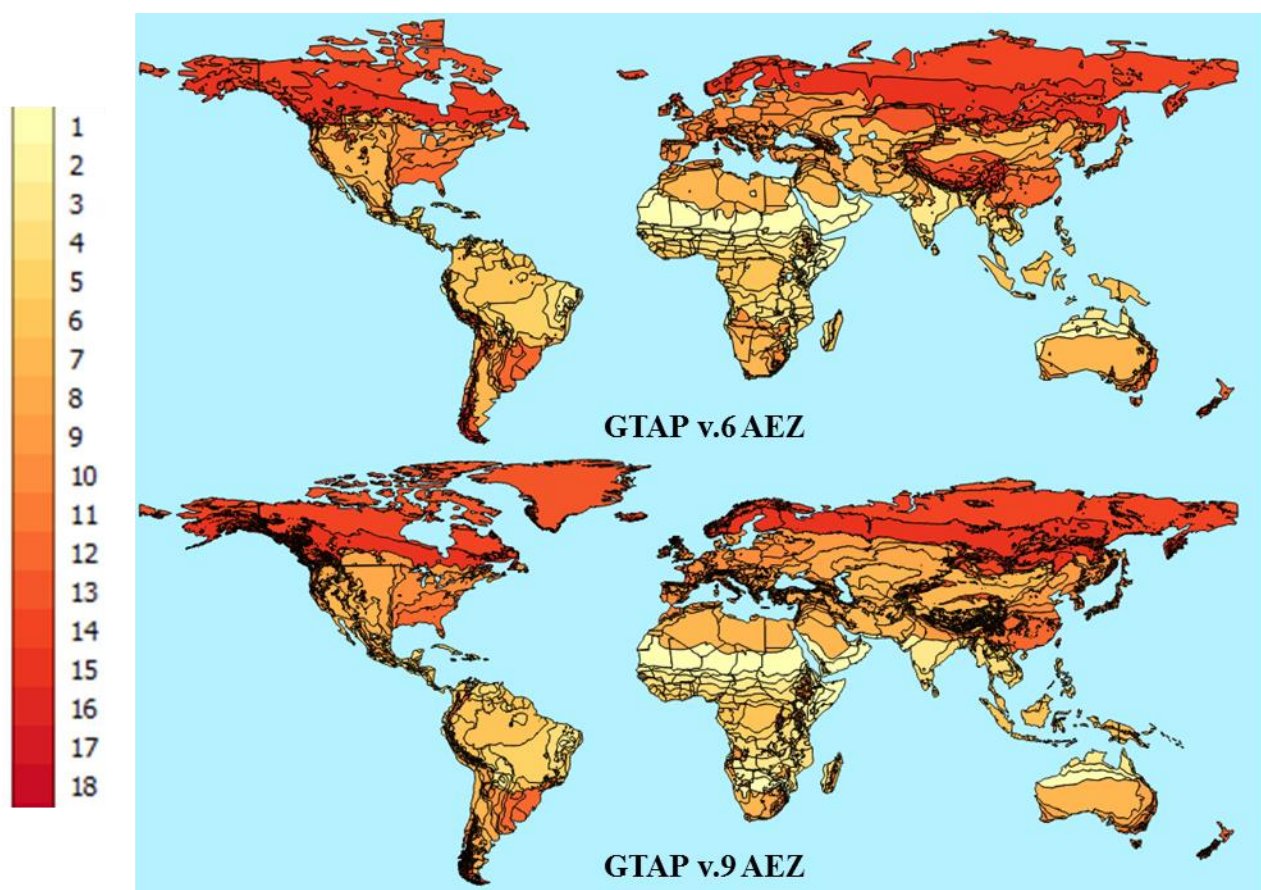
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138	msr	XCB	XCB	MSR	Montserrat
139	mtq	FRA	FRA	MTQ	Martinique
140	mus	MUS	MUS	MUS	Mauritius
141	mwi	MWI	MWI	MWI	Malawi
142	mys	MYS	MYS	MYS	Malaysia
143	myt	XEC	XEC	MYT	Mayotte
144	nam	NAM	NAM	NAM	Namibia
145	ncl	XOC	XOC	NCL	New Caledonia
146	ner	XWF	XWF	NER	Niger
147	nfk	AUS	AUS	NFK	Norfolk Island
148	nga	NGA	NGA	NGA	Nigeria
149	nic	NIC	NIC	NIC	Nicaragua
150	niu	XOC	XOC	NIU	Niue
151	nld	NLD	NLD	NLD	Netherlands
152	nor	NOR	NOR	NOR	Norway
153	npl	NPL	NPL	NPL	Nepal
154	nru	XOC	XOC	NRU	Nauru
155	nzl	NZL	NZL	NZL	New Zealand
156	omn	OMN	OMN	OMN	Oman
157	pak	PAK	PAK	PAK	Pakistan
158	pan	PAN	PAN	PAN	Panama
159	per	PER	PER	PER	Peru
160	phl	PHL	PHL	PHL	Philippines
161	plw	XOC	XOC	PLW	Palau
162	png	XOC	XOC	PNG	Papua New Guinea
163	pol	POL	POL	POL	Poland
164	pri	PRI	PRI	PRI	Puerto Rico
165	prk	XEA	XEA	PRK	Democratic People's Republic of Korea
166	prt	PRT	PRT	PRT	Portugal
167	pry	PRY	PRY	PRY	Paraguay
168	pse	XWS	XWS	PSE	Occupied Palestinian Territory
169	pyf	XOC	XOC	PYF	French Polynesia
170	qat	QAT	QAT	QAT	Qatar
171	reu	FRA	FRA	REU	R,union
172	rom	ROU	ROU	ROU	Romania
173	rus	RUS	RUS	RUS	Russian Federation
174	rwa	RWA	RWA	RWA	Rwanda
175	sau	SAU	SAU	SAU	Saudi Arabia
176	scg	XER	XER	SRB	Serbia and Montenegro
177	sdn	XEC	XEC	SDN	Sudan (former)
178	sen	SEN	SEN	SEN	Senegal
179	sgp	SGP	SGP	SGP	Singapore
180	shn	XWF	XWF	SHN	Saint Helena, Ascension and Tristan da Cunha
181	slb	XOC	XOC	SLB	Solomon Islands
182	sle	XWF	XWF	SLE	Sierra Leone
183	slv	SLV	SLV	SLV	El Salvador
184	smr	XER	XER	SMR	San Marino
185	som	XEC	XEC	SOM	Somalia
186	spm	XNA	XNA	SPM	Saint Pierre and Miquelon
187	stp	XCF	XCF	STP	Sao Tome and Principe
188	sur	XSM	XSM	SUR	Suriname
189	svk	SVK	SVK	SVK	Slovakia
190	svn	SVN	SVN	SVN	Slovenia
191	swe	SWE	SWE	SWE	Sweden
192	swz	XSC	XSC	SWZ	Swaziland
193	syc	XEC	XEC	SYC	Seychelles
194	syr	XWS	XWS	SYR	Syrian Arab Republic
195	tca	XCB	XCB	TCA	Turks and Caicos Islands
196	tcd	XCF	XCF	TCD	Chad
197	tgo	TGO	TGO	TGO	Togo
198	tha	THA	THA	THA	Thailand
199	tjk	XSU	TJK	TJK	Tajikistan
200	tkl	XOC	XOC	TKL	Tokelau
201	tkm	XSU	XSU	TKM	Turkmenistan
202	tls	XSE	XSE	TLS	Timor-Leste
203	ton	XOC	XOC	TON	Tonga
204	tto	TTO	TTO	TTO	Trinidad and Tobago
205	tun	TUN	TUN	TUN	Tunisia
206	tur	TUR	TUR	TUR	Turkey
207	tuv	XOC	XOC	TUV	Tuvalu

208	tw	TWN	TWN	TWN	China, Taiwan Province of
209	tza	TZA	TZA	TZA	United Republic of Tanzania
210	uga	UGA	UGA	UGA	Uganda
211	ukr	UKR	UKR	UKR	Ukraine
212	ury	URY	URY	URY	Uruguay
213	usa	USA	USA	USA	United States of America
214	uzb	XSU	XSU	UZB	Uzbekistan
215	vct	XCB	XCB	VCT	Saint Vincent and the Grenadines
216	ven	VEN	VEN	VEN	Venezuela (Bolivarian Republic of)
217	vgb	XCB	XCB	VGB	British Virgin Islands
218	vir	XCB	XCB	VIR	United States Virgin Islands
219	vn	VNM	VNM	VNM	Viet Nam
220	vut	XOC	XOC	VUT	Vanuatu
221	wlf	XOC	XOC	WLF	Wallis and Futuna Islands
222	wsm	XOC	XOC	WSM	Samoa
223	yem	XWS	XWS	YEM	Yemen
224	zaf	ZAF	ZAF	ZAF	South Africa
225	zmb	ZMB	ZMB	ZMB	Zambia
226	zwe	ZWE	ZWE	ZWE	Zimbabwe

Appendix III. AEZ mapping

AEZ	Length of Growing Days	Thermal Climate
AEZ1	0	59
AEZ2	60	119
AEZ3	120	179
AEZ4	180	239
AEZ5	240	299
AEZ6	300	360
Tropics		
AEZ7	0	59
AEZ8	60	119
AEZ9	120	179
AEZ10	180	239
AEZ11	240	299
AEZ12	300	360
Tropics cool + subtropics + temperate cool		
AEZ13	0	59
AEZ14	60	119
AEZ15	120	179
AEZ16	180	239
AEZ17	240	299
AEZ18	300	360
Temperate cold to boreal		

Appendix IV. Comparison of GTAP LULC v.6 and v.9 AEZs



Appendix V. Crop commodity mapping

GTAP	GTAPNAMES	FAOCODE	FAONAME
1	Barley	44	Barley
2	Buckwheat	89	Buckwheat
3	CanarySeed	101	Canary seed
4	Cerealsnes	108	Cereals, nes
5	Fonio	94	Fonio
6	Maize	56	Maize
7	Millet	79	Millet
8	MixedGrain	103	Mixed grain
9	Oats	75	Oats
10	PopCorn	68	Popcorn
11	Quinoa	92	Quinoa
12	PaddyRice	27	Rice, paddy
13	Rye	71	Rye
14	Sorghum	83	Sorghum
15	Triticale	97	Triticale
16	Wheat	15	Wheat
17	Abaca_M_H	809	Manila Fibre (Abaca)
18	AgaveFibrNES	800	Agave Fibres Nes
19	Coir	813	Coir
20	FibreCropNES	821	Fibre Crops Nes
21	FlaxFibr_Tow	773	Flax fibre and tow
22	HempFibr_Tow	777	Hemp Tow Waste
23	Jute	780	Jute
24	JuteLikeFibr	782	Other Bastfibres
25	KapokFibre	778	Kapok Fibre
26	KapksdShell	311	Kapokseed in Shell
27	Ramie	788	Ramie
28	SeedCotton	328	Seed cotton
29	Sisal	789	Sisal
30	Alff4FrgSlg	641	Alff4FrgSlg
31	Beets4Fodder	647	Beets4Fodder
32	Cabbage4Fddr	644	Cabbage4Fddr
33	Carrots4Fddr	648	Carrots4Fddr
34	Clovr4FrgSlg	640	Clovr4FrgSlg
35	FrgProdNES	651	FrgProdNES
36	GrsNESFrgSlg	639	GrsNESFrgSlg
37	GmOlsd4Fddr	642	GmOlsd4Fddr
38	LgmNESFrgSlg	420	Leguminous vegetables, nes
39	Maize4FrgSlg	636	Maize4FrgSlg
40	MxGrss_Lgm	645	MxGrss_Lgm
41	RyeGrsFrgSlg	638	RyeGrsFrgSlg
42	Srgm4FrgSlg	637	Srgm4FrgSlg
43	Swedes4Fddr	649	Swedes4Fddr
44	Turnips4Fddr	646	Turnips4Fddr
45	Vgt_RootFddr	655	Vgt_RootFddr
46	Apples	515	Apples
47	Apricots	526	Apricots
48	Avocados	572	Avocados
49	Bananas	486	Bananas
50	Berriesnes	558	Berries Nes
51	Blueberries	552	Blueberries
52	Carobs	461	Carobs
53	Cashewapple	591	Cashewapple
54	Cherries	531	Cherries
55	CitrusFrtNES	512	Citrus fruit, nes
56	Cranberries	554	Cranberries
57	Currants	550	Currants
58	Dates	577	Dates
59	Figs	569	Figs
60	FrtFrshNES	619	Fruit Fresh Nes
61	FrtTrpFrNES	603	Fruit, tropical fresh nes
62	Gooseberries	549	Gooseberries
63	Grpfrt_Pmlos	507	Grapefruit (inc. pomelos)
64	Grapes	560	Grapes
65	KiwiFruit	592	Kiwi fruit
66	Lmn_Lme	497	Lemons and limes
67	Mangoes	571	Mangoes, mangosteens, guavas

68	Oranges	490	Oranges
69	Papayas	600	Papayas
70	Peach_Nctm	534	Peaches and nectarines
71	Pears	521	Pears
72	Persimmons	587	Persimmons
73	Pineapples	574	Pineapples
74	Plantains	489	Plantains
75	Plums	536	Plums and sloes
76	Quinces	523	Quinces
77	Raspberries	547	Raspberries
78	SourCherries	530	Sour cherries
79	StnFrtNESFrh	541	Stone fruit, nes
80	Strawberries	544	Strawberries
81	TngMndCImnt	495	Tangerines, mandarins, clem.
82	CastorBeans	265	Castor oil seed
83	Coconuts	249	Coconuts
84	GrmdntWShll	242	Groundnuts, with shell
85	Hempseed	336	Hempseed
86	KrtNtSheant	263	Karite Nuts (Sheanuts)
87	Linseed	333	Linseed
88	Melonseed	299	Melonseed
89	MustardSeed	292	Mustard seed
90	OilPalmFruit	254	Oil palm fruit
91	Oilseedsnes	339	Oilseeds, Nes
92	Olives	260	Olives
93	PoppySeed	296	Poppy seed
94	Rapeseed	270	Rapeseed
95	SfflwrSeed	280	Safflower seed
96	SesameSeed	289	Sesame seed
97	Soybeans	236	Soybeans
98	SnflwrSeed	267	Sunflower seed
99	TungNuts	275	Tung Nuts
100	Ans_bdn_fnnl	711	Anise, badian, fennel, corian.
101	ArcNtBtl	226	Arecanuts
102	ChicoryRoots	459	Chicory roots
103	CnnmnCnlla	693	Cinnamon (canella)
104	cloves	698	Cloves
105	CocoaBeans	661	Cocoa beans
106	CoffeeGreen	656	Coffee, green
107	ginger	720	Ginger
108	Hops	677	Hops
109	Kolanuts	224	Kolanuts
110	Mate	671	Maté
111	NaturalGums	839	Gums Natural
112	NatRubber	836	Natural rubber
113	Ntmg_Mc_Crdm	702	Nutmeg, mace and cardamoms
114	Pepper	687	Pepper (Piper spp.)
115	Peppermint	748	Peppermint
116	Pimento	689	Chillies and peppers, dry
117	PrthrmDrdFlw	754	Pyrethrum, Dried
118	spicesnes	723	Spices, nes
119	Tea	667	Tea
120	TbccLeaves	826	Tobacco, unmanufactured
121	Vanilla	692	Vanilla
122	BambaraBeans	203	Bambara beans
123	BeansDry	176	Beans, dry
124	BrdBeansDry	181	Broad beans, horse beans, dry
125	ChickPeas	191	Chick peas
126	CowPeasDry	195	Cow peas, dry
127	Lentils	201	Lentils
128	Lupins	210	Lupins
129	PeasDry	187	Peas, dry
130	PigeonPeas	197	Pigeon peas
131	Pulsesnes	211	Pulses, nes
132	Vetches	205	Vetches
133	Cassava	125	Cassava
134	Potatoes	116	Potatoes
135	Root_TbrNES	149	Roots and Tubers, nes
136	SweetPotato	122	Sweet potatoes
137	TaroCocoYam	136	Taro (cocoyam)
138	Yams	137	Yams

139	YautiaCcYam	135	Yautia (cocoyam)
140	SugarBeets	157	Sugar beet
141	SugarCane	156	Sugar cane
142	SugarCrpNES	161	Sugar crops, nes
143	Almonds	221	Almonds, with shell
144	BrazilNuts	216	Brazil nuts, with shell
145	CashewNuts	217	Cashew nuts, with shell
146	Chestnuts	220	Chestnuts
147	HzlntFlbrt	225	Hazelnuts, with shell
148	Nutsnes	234	Nuts, nes
149	Pistachios	223	Pistachios
150	Walnuts	222	Walnuts, with shell
151	Artichokes	366	Artichokes
152	Asparagus	367	Asparagus
153	BeanGreen	414	Beans, green
154	BrdBeanGreen	9003	BrdBeanGreen
155	Cabbages	358	Cabbages and other brassicas
156	Cntlp_othMln	568	Other melons (inc.cantaloupes)
157	Carrots	426	Carrots and turnips
158	Cauliflower	393	Cauliflowers and broccoli
159	Chll_PpprGrn	401	Chillies and peppers, green
160	Ccmbr_Ghrkn	397	Cucumbers and gherkins
161	Eggplants	399	Eggplants (aubergines)
162	Garlic	406	Garlic
163	GrnCornMaize	446	Maize, green
164	Lettuce	372	Lettuce and chicory
165	Mushrooms	449	Mushrooms and truffles
166	Okra	430	Okra
167	OnionDry	403	Onions, dry
168	OnionShlltGn	402	Onions (inc. shallots), green
169	PeasGreen	417	Peas, green
170	PmpknSqshGrd	394	Pumpkins, squash and gourds
171	Spinach	373	Spinach
172	StringBeans	423	String beans
173	Tomatoes	388	Tomatoes
174	VgtbFrshNES	463	Vegetables fresh nes
175	Watermelons	567	Watermelons
