03

B: The future of ecosystem services: Global and national scenarios

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Introduction

Ecosystem services are a major contributor to sustainable human well-being. Between 1997 and 2011, it has been estimated that the global value of these services has decreased by USD 20 trillion/yr due to land use change[1]. In this chapter, three existing sets of global scenarios[2,3,4] are aggregated to develop and evaluate the future value of global ecosystem services under four alternative land-use scenarios (*Table 3b.1*). The scenarios are a synthesis of prior scenario studies, but are based around the four 'Great Transition Initiative' (GTI) archetypes[5], which provide a range of plausible futures that impact on land and water use and management. This chapter estimates the implications of these scenarios for the value of ecosystem services to 2050. The GTI scenarios are described in more detail later, but in summary are:

1. **Market Forces (MF):** an economic and population growth archetype based on neoliberal free market assumptions;
2. **Fortress World (FW):** an archetype in which nations and the world become fragmented, inequitable, and head towards temporary or permanent social collapse;
3. **Policy Reform (PR):** a continuing economic growth but with discipline/restraint/regulation archetype based on assumptions about the need for government intervention and effective policy; and,
4. **Great Transition (GT):** a transformation archetype based on assumptions about limits to conventional GDP growth and more focus on environmental and social well-being and sustainability.

The value of ecosystem services in these four scenarios were evaluated for the world as a whole and for selected countries and regions, including Kenya, France, Australia, China, United States, and Uruguay, plus a global table. Regional data is also analysed in *Chapter 4*. Results show that under the MF and FW scenarios the value of ecosystem services continues to decline, while in the PR scenario the value is maintained or slightly increased, and in the GT scenario the value is significantly restored.

Global value of ecosystem services

Ecosystems are the life support system of our planet[1,6,7]. However, over the past several decades, the services that they provide (see *Chapter 1*) have been significantly degraded. In 2011, the total value of global ecosystem services were estimated to be USD 125 trillion/year. This value was estimated to be a decrease of USD 20.2 trillion/year from 1997 due to land use and management changes[1,6] – a trend which is currently continuing. Interest in ecosystem services in both the research and policy communities is growing rapidly[8,9,10]. This chapter investigates alternative and plausible land-use scenarios which could either accelerate or reverse land degradation and the resulting value of ecosystem services.

Scenario planning

Scenario analysis or scenario planning is defined as a 'structured process of exploring and evaluating alternative futures'. Scenarios combine influential and uncertain drivers that have low controllability into storylines of the future[11]. Ultimately, the goal of scenario planning is to illustrate the consequences of these drivers and policy options, reveal potential tipping points[12], and inform and improve decisions. Unlike forecasting, projections, and predictions, scenarios explore plausible rather than probable futures[13].

Scenario planning has become an important way to inform decision-making incorporating a whole-system perspective under uncertainty[14,15]. Scenarios have been used at all scales, from individual corporations to communities to global[4]. This chapter uses the highly developed GTI scenarios, and their implications for ecosystem services out to 2050 are estimated.

Methods

Global and national land use change scenarios

The Great Transition Initiative (GTI) scenarios have been worked out in some detail for both the global system and several regions.[i] Brief narrative descriptions of each scenario, extracted from the GTI website, are reproduced here.

Market Forces

The *Market Force* scenario is a story of a market-driven world in the 21st century in which demographic, economic, environmental and technological trends unfold without major surprise relative to unfolding trends. Continuity, globalisation, and convergence are key characteristics of world development – institutions gradually adjust without major ruptures, international economic integration proceeds apace, and the socioeconomic patterns of poor regions converge slowly toward the development model of the rich regions. Despite economic growth, extreme income disparity between rich and poor countries, and between the rich and poor within countries, remains a critical social trend. Environmental transformation and degradation are a progressively more significant factor in global affairs.

Policy Reform

The *Policy Reform* scenario envisions the emergence of strong political will for taking harmonised and rapid action to ensure a successful transition to a more equitable and environmentally resilient future. Rather than a projection into the future, the *PR* scenario is a normative scenario constructed as a backcast from the future. It is designed to achieve a set of future sustainability goals. The analytical task is to identify plausible development pathways for reaching that end-point. Thus, the *PR* scenario explores the requirements for simultaneously achieving social and environmental sustainability goals under high economic growth conditions similar to those of *Market Forces*.

Fortress World

The *Fortress World* scenario is a variant of a broader class of *Barbarization scenarios*, in the hierarchy of

[i] *www.greattransition.org/explore/scenarios*

the Global Scenario Group[16]. *Barbarization scenarios* envision the grim possibility that the social, economic and moral underpinnings of civilisation deteriorate, as emerging problems overwhelm the coping capacity of both markets and policy reforms. The *FW* variant of the Barbarization story features an authoritarian response to the threat of breakdown. Ensconced in protected enclaves, elites safeguard their privilege by controlling an impoverished majority and managing critical natural resources, while outside the fortress there is repression, environmental destruction and misery

Great Transition

The *Great Transition* scenario explores visionary solutions to the sustainability challenge, including new socio-economic arrangements and fundamental changes in values. This scenario depicts a transition to a society that preserves natural systems, provides high levels of welfare through material sufficiency and equitable distribution, and enjoys a strong sense of local solidarity.

Each of these scenarios has implications for land use and management. The interactive web tool, "Futures in Motion" on the GTI website was used to derive estimates of land use change, population, GDP, and other variables for these four future scenarios to the year 2050[ii] (*Table 3b.1*). The GTI scenarios did not, however, include changes in wetlands. These were estimated based on past trends in wetland loss seen between 1997 and 2011 for the MF and FW scenarios[1,6,7], a policy of 'no net loss' for the PR scenario, and an aspirational wetland restoration policy for the GT scenario. These changes are described in more detail later in the section on results.

[ii] *www.tellus.org/results/results_World.html*

Unit value change scenarios

The change in global value of ecosystem services in these scenarios was hypothesised to be due to two factors: 1) change in area covered by each ecosystem type; and 2) change in the "unit value" – the aggregate value of all the marketed and non-marketed ecosystem services per ha per year of each ecosystem type due to degradation or restoration (see *Table 3b.2*). These changes relate to how land or water are managed, on average. These effects were separated out by evaluating the scenarios in two ways: a) using the 2011 unit values estimated by Costanza *et al.* (2014)[1] and only changing land use; and b) changing both unit values and land use. Like all estimates at this scale, this is a simplification. But for the purposes of this exercise, authors believed it sufficient. Obviously, much more elaborate and sophisticated modelling and analysis can be done[17], but this is left for future studies.

The unit value changes were based on policy and management assumptions likely to occur in each scenario. For example, in the PR scenario, it was assumed that a slight improvement in policies around the environment and ecosystem services would allow maintenance of the 2011 unit values until 2050, while in FW, unit values would decrease by 20 per cent on average. These percent changes were based roughly on the estimates included in the Bateman *et al.* (2013)[3] study of six future scenarios for the UK. However, they are not intended to be empirically derived, but rather are plausible estimates of the magnitude of change that could occur under each hypothetical scenario. In general, the following was assumed for each of the four scenarios:

1. **Market Forces-Free Enterprise:** decrease in attention to environmental and non-market factors resulting in an average *10 per cent reduction in unit values* from their 2011 levels. This is also in a world where climate change has not been dealt with.
2. **Fortress World-Strong Individualism:** *significant* decrease in attention to environmental and non-market factors resulting in an average *20 per cent reduction in unit values* from their 2011 levels. This is also in a world where climate change has accelerated.
3. **Policy Reform-Coordinated Action:** slight improvement from 2011 policies and management leading to *no significant change in unit values* from their 2011 estimates. This is also in a world where climate change has been moderated.
4. **Great Transition-Community Well-Being:** *significant* increase in attention to environmental and non-market factors resulting in an average *20 per cent increase in unit values* from their 2011 levels. This is also in a world where climate change has been addressed.

Mapping

Creation of the spatial data layers for the four scenarios was done via a loose coupling with the scenario projection modelling. The modelling of each scenario generated a change in land cover for the following types: Urban, Wetland, Cropland, Forest, Grassland, and Desert. Authors started with a modified version of the GlobCov data product[1] which was used as the original base data. For each scenario, the landcover base was grown or shrunken based on the percentage changes of that landcover scenario projection. All growth and loss were adjacent to the existing original extent of that landcover. The order of precedence for these landcover changes was as follows: Urban, Wetland, Cropland, Forest, Rangeland/Grassland, and Desert. This precedence worked in such a way that all previous landcover transitions are excluded from subsequent conversion (e.g., cropland can not replace urban or wetlands). The results of these models can be presented as tables and as maps for any country or region in the world, and this chapter presents an example of Kenya.

Results and discussion

Global scenarios

Table 3b.2 shows the land area, unit values, and the total annual flow value for each of the biomes. It also shows the total annual ecosystem service flow value for each scenario. The black numbers show values that have remained the same in each scenario as compared to the 2011 values, numbers in red show a decrease, and green numbers show an increase. Using the land use changes for each biome derived from estimates by the Great Transition Initiative shown in *Table 3b.1*[2], the land area of forests (both tropical and temperate/boreal) and grass/rangelands decreased significantly in all scenarios except GT, as compared to 2011 areas. Wetlands (both tidal marshes/mangroves and swamps/floodplains) and ice/rock decreased in the MF and FW scenario, while increased or remained the same in PR and GT. Desert increased in all the scenarios except GT and tundra decreased in all scenarios. Cropland and urban both increased in unit areas in all four scenarios. On the marine

TABLE 3B.1

Future global land use areas and other variables for each of the four scenarios from the GTI website

ELD Scenarios	**1997**	**2011**	**1. MF**	**2. FW**	**3. PR**	**4. GT**
Great Transition Initiative (GTI)			Market Forces	Fortress World	Policy Reform	Great Transition
Costanza *et al.* 2014			Free Enterprise	Strong Individualism	Coordinated Action	Community Well-Being
Bateman *et al.* 2013			Focus on Market Growth	Maintain Current Practices	Green and Pleasant Land	Conservation Fully Implemented
Population (e9)	5.9	7	9.08	9.53	8.68	8.08
– Urban pop (e9)	2.75	3.5	6.25	6.57	5.99	5.57
– Rural pop (e9)	3.15	3.5	2.83	2.96	2.69	2.51
Inequality (Richest 10%/Poorest 10%)		16	29.4	53	14.9	7.1
Urban land (e6 ha)	332	350	554	675	490	397
Cropland (e6 ha)	1400	1672	1757	1782	1733	1676
Forest (e6 ha)	4855	4261	3450	3541	3989	4313
Grass/Rangeland (e6 ha)	3898	4418	3991	3696	4219	4483
Desert (e6 ha)	1925	2159	3396	3494	2427	1924

TABLE 3B.2

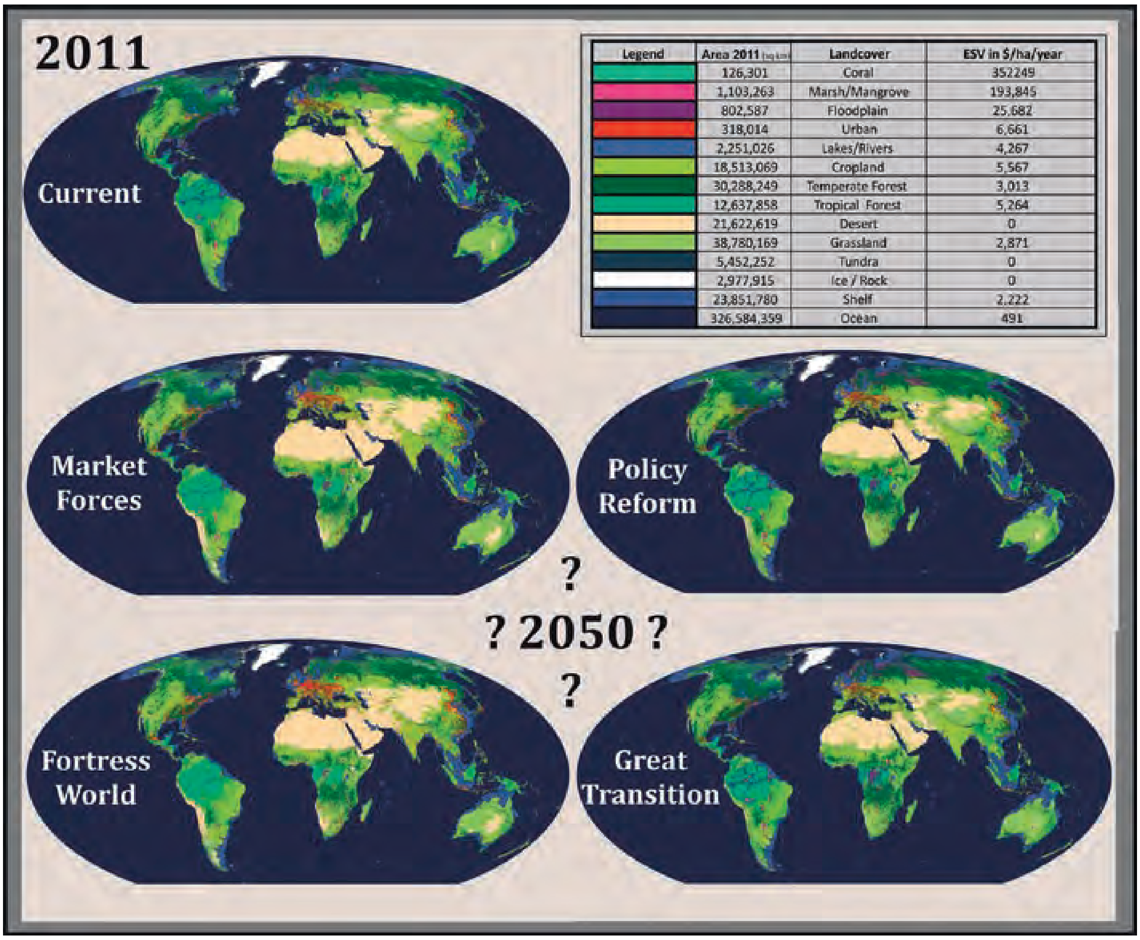
Changes in area, unit values, and aggregate global flow values from 1997 to 2011 and for four future scenarios to the year 2050

Biome	Area (e6 ha)						% Change	-0,1	-0,2	0	0,2	Total Annual Flow of Eco-Services Values (e12 2007$/yr)					
							Unit Values ($2007/ha/yr)										
	(e6 ha)		Scenarios to 2050				($/ha)	Scenarios to 2050				(e12 $/yr)		Scenarios to 2050			
	1997	2011	1. MF	2. FW	3. PR	4. GT	2011	1. MF	2. FW	3. PR	4. GT	1997	2011	1. MF	2. FW	3. PR	4. GT
Marine	**36.302**	**36.302**	**36.302**	**36.302**	**36.302**	**36.302**	**1.368**	**1.231**	**1.094**	**1.368**	**1.642**	**60,5**	**49,7**	**38,0**	**32,5**	**49,7**	**62,3**
Open Ocean	33.200	33.200	33.200	33.200	33.200	33.200	660	594	528	660	792	21,9	21,9	19,7	17,5	21,9	26,3
Coastal	3.102	3.102	3.102	3.102	3.102	3.102	8.944	8.050	7.155	8.944	10.733	38,6	27,7	18,3	15,0	27,7	36,0
Estuaries	180	180	180	180	180	180	28.916	26.024	23.133	28.916	34.699	5,2	5,2	4,7	4,2	5,2	6,2
Algae Beds/Seagrass	200	234	257	262	234	227	28.916	26.024	23.133	28.916	34.699	5,8	6,8	6,7	6,1	6,8	7,9
Coral Reefs	62	28	5	0	28	35	352.249	317.024	281.799	352.249	422.699	21,7	9,9	1,6	0,0	9,9	14,8
Shelf	2.660	2.660	2.660	2.660	2.660	2.660	2.222	2.000	1.777	2.222	2.666	5,9	5,9	5,3	4,7	5,9	7,1
Terrestrial	**15.323**	**15.323**	**15.323**	**15.323**	**15.323**	**15.323**	**4.901**	**4.411**	**3.921**	**4.901**	**5.881**	**84,5**	**75,1**	**50,4**	**40,7**	**78,3**	**101,7**
Forest	4.855	4.261	3.450	3.541	3.989	4.313	3.800	3.420	3.040	3.800	4.560	19,5	16,2	11,8	10,8	15,2	19,7
Tropical	1.900	1.258	1.019	1.045	1.178	1.273	5.382	4.844	4.306	5.382	6.458	10,2	6,8	4,9	4,5	6,3	8,2
Temperate/Boreal	2.955	3.003	2.432	2.495	2.812	3.039	3.137	2.823	2.510	3.137	3.764	9,3	9,4	6,9	6,3	8,8	11,4
Grass/Rangelands	3.898	4.418	3.991	3.696	4.219	4.483	4.166	3.749	3.333	4.166	4.999	16,2	18,4	15,0	12,3	17,6	22,4
Wetlands	330	188	75	35	225	290	140.174	126.157	112.139	140.174	168.209	36,2	26,4	9,3	4,1	30,2	42,2
Tidal Marsh/Mangroves	165	128	50	25	145	165	193.843	174.459	155.074	193.843	232.612	32,0	24,8	8,7	3,9	28,1	38,4
Swamps/Floodplains	165	60	25	10	80	125	25.681	23.113	20.545	25.681	30.817	4,2	1,5	0,6	0,2	2,1	3,9
Lakes/Rivers	200	200	200	200	200	200	12.512	11.261	10.010	12.512	15.014	2,5	2,5	2,3	2,0	2,5	3,0
Desert	1.925	2.159	3.396	3.494	2.427	1.924	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
Tundra	743	433	300	300	400	400	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
Ice/Rock	1.640	1.640	1.600	1.600	1.640	1.640	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0	0,0
Cropland	1.400	1.672	1.757	1.782	1.733	1.676	5.567	5.010	4.454	5.567	6.680	7,8	9,3	8,8	7,9	9,6	11,2
Urban	332	352	554	675	490	397	6.661	5.995	5.329	6.661	7.993	2,2	2,3	3,3	3,6	3,3	3,2
Total	**51.625**	**51.625**	**51.625**	**51.625**	**51.625**	**51.625**						**145,0**	**124,8**	**88,4**	**73,2**	**128,0**	**164,0**

black values are values that have remained constant, **green** are values that have increased, **red** are values that have decreased from the 2011 values

FIGURE 3B.1

Global land cover 'Base Data', 'Scenario 1 – Market Forces', 'Scenario 2 – Fortress World', 'Scenario 3 – Policy Reform','Scenario 4 – Great Transition'



Legend	Area 2011 (sq km)	Landcover	ESV in $/ha/year
	126,301	Coral	352249
	1,103,263	Marsh/Mangrove	193,845
	802,587	Floodplain	25,682
	318,014	Urban	6,661
	2,251,026	Lakes/Rivers	4,267
	18,513,069	Cropland	5,567
	30,288,249	Temperate Forest	3,013
	12,637,858	Tropical Forest	5,264
	21,622,619	Desert	0
	38,780,169	Grassland	2,871
	5,452,252	Tundra	0
	2,977,915	Ice / Rock	0
	23,851,780	Shelf	2,222
	326,584,359	Ocean	491

side, algae beds/seagrass increased in MF and FW, remained the same in PR, and decreased in GT. Coral reef extent decreased in MF and FW, remained the same in PR, and increased in GT. Even though marine systems are not 'land', their functioning is highly influenced by land-based activity, especially coastal systems like coral reefs. The unit values per biome were adjusted from 2011 values as described above. However, the results with unit values, unchanged from 2011 are also shown for comparison (*Figure 3b.3*). The general trends and conclusions are unchanged, only the magnitudes are different.

Putting the land areas and unit values together for each biome, the global total annual flow of ecosystem services values was estimated (*Figure 3b.2*). The total values in both MF and FW were all lower than in 2011, dropping to USD 88.4 and 73.2 trillion/year respectively, from a 2011 value of USD 124.8 trillion/yr. The values in PR increased a small amount to USD 128 trillion/year, mostly due to the fact that marine values did not change, forest and grassland/rangelands decreased, and wetlands, croplands, and urban increased. GT, on the other hand, increased to USD 164 trillion/year.

Figure 3b.3 compares the difference between total annual ecosystem services value when the unit values are changed for each biome (based on the different priorities embodied in each of the scenarios) and when the values are left at those used in 2011. MF and FW decreased from 2011 values to USD 98.3 and 91.5 trillion/yr, respectively, and PR and GT increased to USD 128 and 136.7 trillion/yr, respectively. The overall pattern remains the

FIGURE 3B.2

Global total annual flow of ecosystem service values

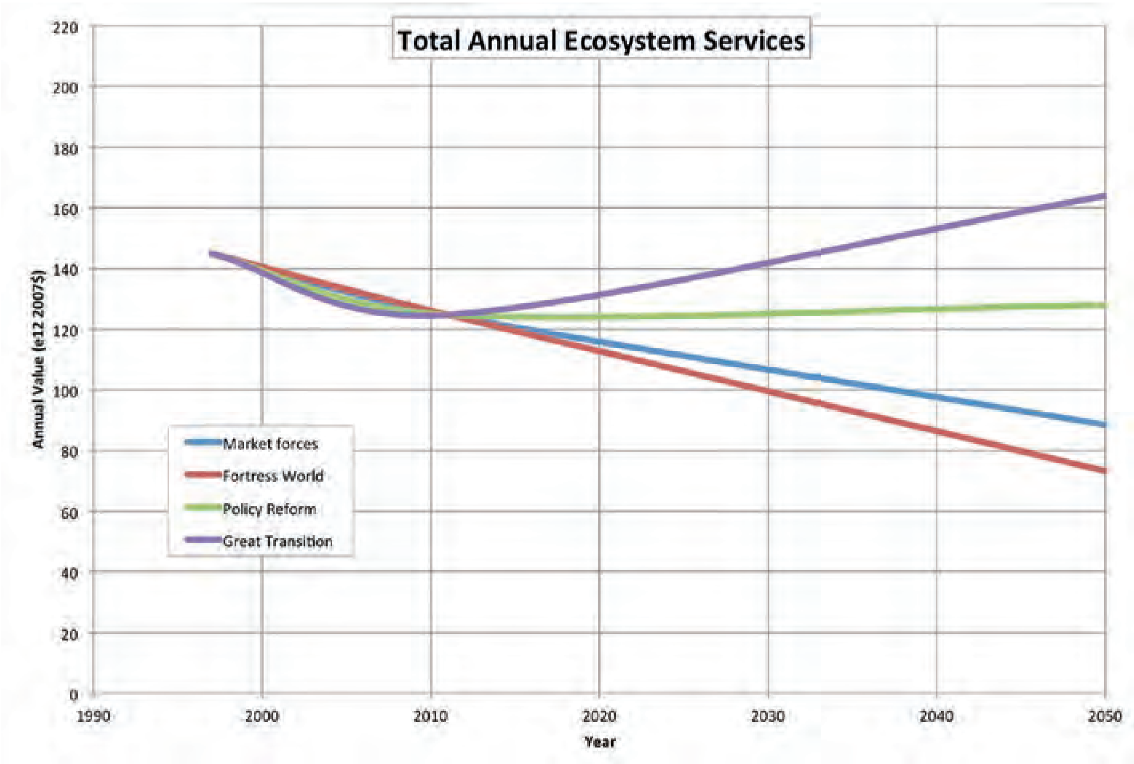


FIGURE 3B.3

Comparison of ecosystem service values

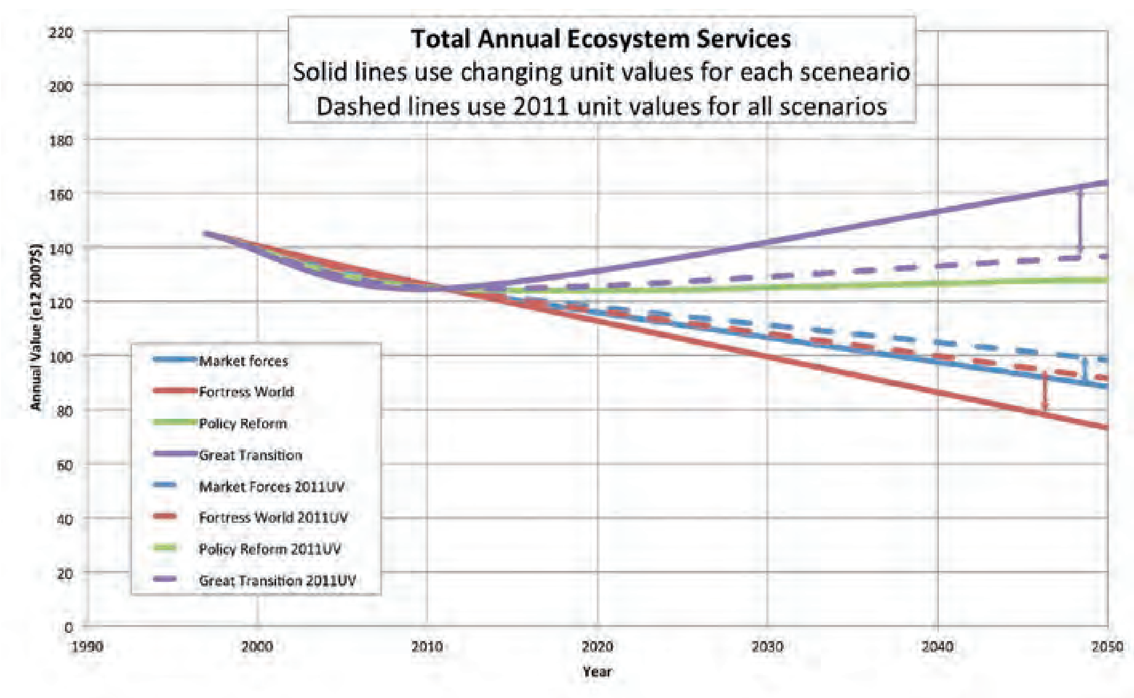
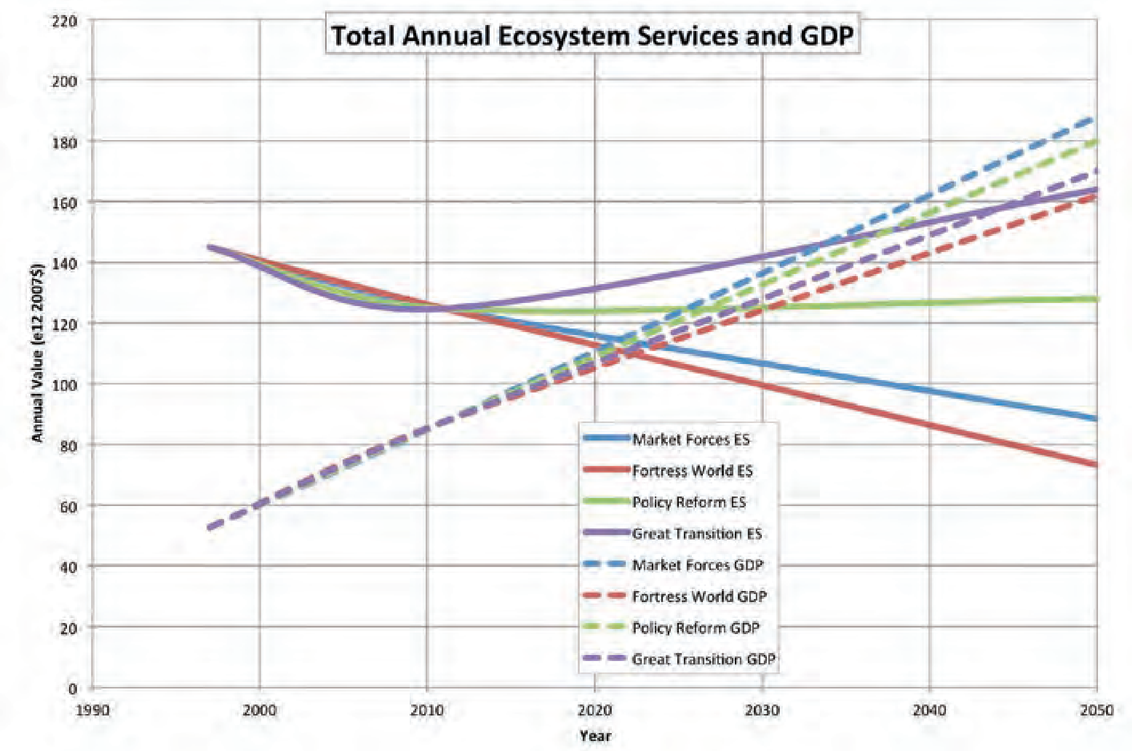


FIGURE 3B.4

The annual value of ecosystem services and GDP for each of the four scenarios



same, but the differences are reduced. This occurs because the changes in unit values amplify the existing changes in area cover of the biomes.

The GDP for each scenario (from the GTI website) is shown in *Figure 3b.4*. MF has the highest GDP as economic growth is the end goal of society in that scenario. PR follows closely behind as it fosters economic growth while simultaneously passing policies to preserve ecosystems and the services they provide. GT comes third because even without the focus on economic growth, the society and economy are healthy and prospering. FW is last since global society is deteriorating, with social, environmental, and economic problems reaching a point of collapse.

Regional scenarios

Using the global model created for the four scenarios, land area changes and impacts on ecosystem services values for any country or region can be looked at individually. The results include maps of land area for each biome, changes to those areas, and the value of ecosystem services for each of the four scenarios within that country or region. They also include a table showing estimations of land area for each biome within each country and the values of their ecosystem services, as done for the global scenarios (*Table 3b.2*). In this report, results for Kenya are shown as an example. However, maps and tables for Australia, China, France, United States, and Uruguay can be found at: *www.eld-initiative.org/index.php?id=122*.

Kenya has a terrestrial land area of 58.5 million ha, which in 2011 was made up of 15 million ha of forest (0.5 million ha tropical and 14 million ha temperate), 35 million ha of grass/rangelands, 0.1 million ha wetlands, 1.1 million ha desert, 6.5 million ha cropland, and 0.2 million ha urban lands. With the four different scenarios, the land use changes in Kenya resembled the pattern of overall global changes. Most of the biomes in MF and FW decreased, except for desert, cropland, and urban. PR saw a similar pattern to MF and FW, except that in this scenario, the area of wetlands increased. In GT, all the biomes increased in area except for desert. The GT scenario involves reversing desertification and investment in restoring other ecosystems (*Table 3b.3*).

TABLE 3B.3

Four transition scenarios and ecosystem service values and flows to 2050, by biome

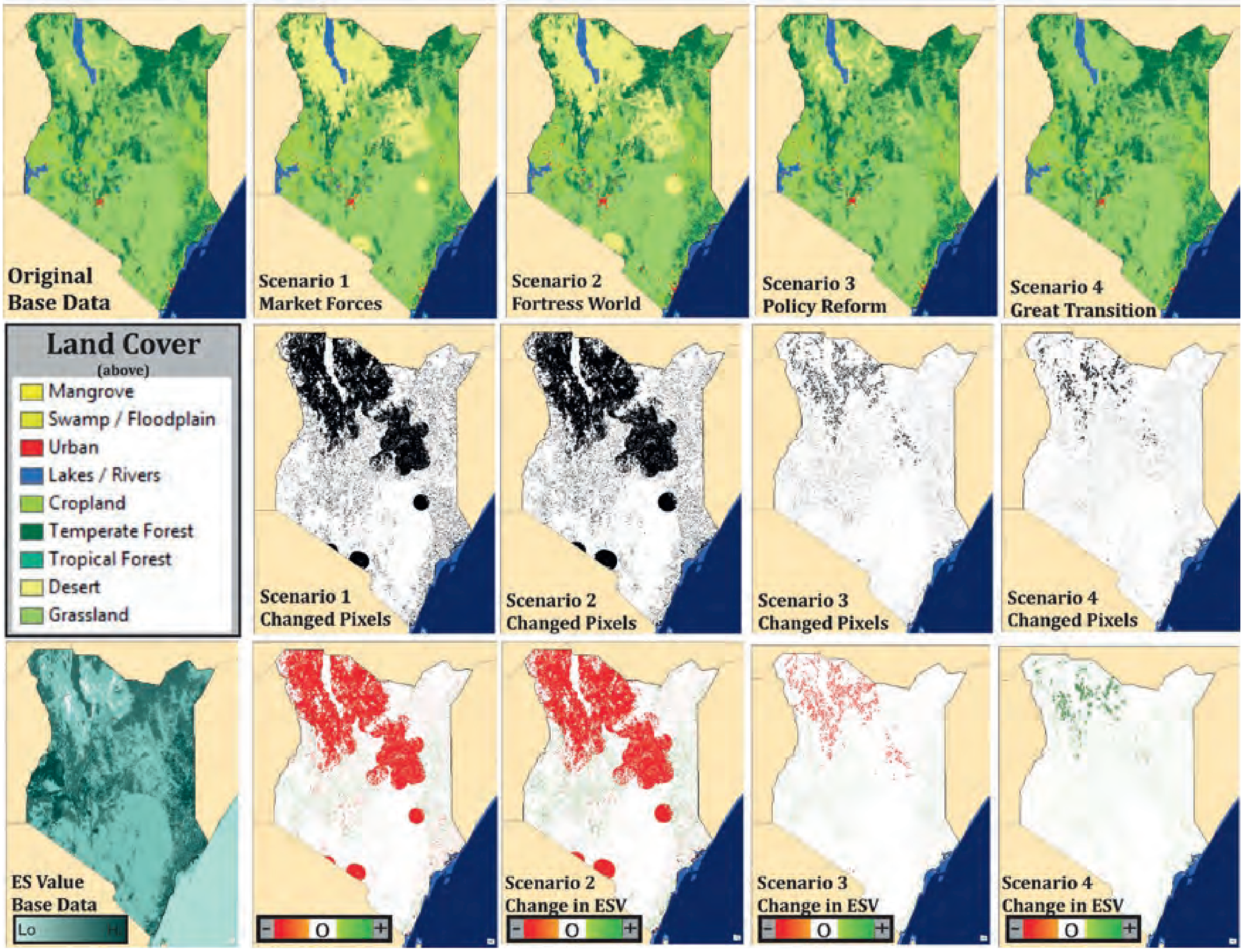
Biome	Area (e6 ha)					% Change	-0,1	-0,2	0	0,2	Total Annual Flow of Eco-Services Values (e12 2007$/yr)				
						Unit Values ($2007/ha/yr)									
	(e6 ha)	Scenarios to 2050				($/ha)	Scenarios to 2050				(e12 $/yr)	Scenarios to 2050			
	2011	1. MF	2. FW	3. PR	4. GT	2011	1. MF	2. FW	3. PR	4. GT	2011	1. MF	2. FW	3. PR	4. GT
Terrestrial	**58,554**	**58,554**	**58,554**	**58,554**	**58,554**	**4,901**	**4,411**	**3,921**	**4,901**	**5,881**	**251.35**	**179.29**	**156.48**	**247.14**	**307.39**
Forest	14,889	11,460	12,263	14,267	15,660	3,800	3,420	3,040	3,800	4,560	47.98	33.18	31.58	45.97	60.48
Tropical	569	410	447	542	567	5,382	4,844	4,306	5,382	6,458	3.06	1.98	1.93	2.92	3.66
Temperate/Boreal	14,320	11,050	11,816	13,725	15,093	3,137	2,823	2,510	3,137	3,764	44.92	31.20	29.65	43.06	56.82
Grass/Rangelands	34,622	24,838	22,899	33,238	34,662	4,166	3,749	3,333	4,166	4,999	144.23	93.13	76.32	138.47	173.28
Wetlands	85.5	12.9	0.1	105.0	146.4	140,174	126,157	112,139	140,174	168,209	6.64	0.81	0.02	6.98	9.80
Tidal Marsh/Mangroves	26.4	3.4	0.1	25.5	26.2	193,843	174,459	155,074	193,843	232,612	5.12	0.59	0.02	4.94	6.09
Swamps/Floodplains	59	10	-	80	120	25,681	23,113	20,545	25,681	30,817	1.52	0.22	0.00	2.04	3.70
Lakes/Rivers	1,206	1,206	1,206	1,206	1,206	12,512	11,261	10,010	12,512	15,014	15.08	13.58	12.07	15.08	18.10
Desert	1,070	13,402	14,073	2,496	79.8	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Tundra	-	-	-	-	-	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Ice/Rock	-	-	-	-	-	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Cropland	6,493	7,298	7,691	6,954	6,576	5,567	5,010	4,454	5,567	6,680	36.15	36.56	34.25	38.71	43.93
Urban	190	339	423	288	225	6,661	5,995	5,329	6,661	7,993	1.26	2.03	2.25	1.92	1.80
Total											**251.35**	**179.29**	**156.48**	**247.14**	**164,0**

The total ecosystem service values for the MF and FW scenarios decrease significantly compared to the 2011 values. FW sees the greatest decrease (of about USD 100 billion), followed closely by MF (USD 70 billion). PR decreases only by about USD 4 billion from the 2011 value, while GT increased by about USD 55 billion (*Table 3b.3*). For comparison, the GDP of Kenya in 2011 was around 94 billion.

Figure 3b.4 shows maps of the biome land use changes for each of the four scenarios compared to the 2011 base map. It also shows which pixels changed between the 2011 base map and that scenario. Scenarios MF and FW showed the greatest changes, while PR and GT the least.

FIGURE 3B.5

Maps of biome land use changes for four scenarios in Kenya, compared to 2011



Top row: Maps of the area change of each biome in Kenya for the base map and the four scenarios

Middle row: Maps of the pixels changed between the base map of 2011 and each of the four scenarios. In the MF and FW maps, there are multiple symmetric circular desert areas. These occur because a single desert pixel in the original base map grew symmetrically outwards from all edges of desert

Bottom row: Maps of the change in the value of ecosystem services between the base map of 2011 and each of the four scenario

The large differences in the total annual ecosystem services values between each of the four scenarios shows the kind of impact that land-use decisions can have going forward. A difference of USD 75.6 trillion/year globally in the value of ecosystem services between the FW and GT can mean life or death for many people, especially those in developing countries[18]. The GT scenario is an ecosystem services restoration scenario. It can reverse the current trends in land degradation and allow for a sustainable and desirable future, and can also address climate change while restoring other critical services, especially those that are important to the poor.

Scenarios are not predictions – they only point out the range of plausible future conditions. They can help policy-/decision-makers deal with uncertainty and design policies to improve the chances of better futures occurring. They can also be used to engage the larger public in thinking about the kind of future they really want. Scenarios can be used as the basis for public opinion surveys to gauge preferences for different futures at the global, regional, national and local scales[4].

Future work can extend these initial analyses by using landscape scale computer simulation models to help create and evaluate scenarios for ecosystem restoration for comparison with business-as-usual[17]. These approaches hold significant promise for reversing land degradation and building a sustainable and desirable future towards sustainable land management, using comprehensive ecological-economic arguments as an aid for better decision-making.

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