DIVERGENT VS. CONVERGENT DEVELOPMENT MODELS.

SUSTAINABILITY SCIENCE SEMINAR

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Introduction

Sustainable development implies the transformation of socio-ecological systems to provide food, water, energy, health and human security, promote cultural diversity, reduce inequality between individuals, increase the possibilities of adaptation to natural and anthropocentric disturbances, develop efficient technologies and low consumption of resources and generate productive structures of distribution and consumption. Such scenario has to be economically, ecologically and socially viable from an inter- and intra-generation perspectives (Carpenter *et al*., 2006; Masera *et al*., 2000).

To accomplish these objectives, different sustainable development models have been studied and implemented. These models can be placed within a gradient between two contrasting approaches. In one extreme is the dominant vision that promotes an intensive land-use in a compartmentalized way, named here as the divergent model. In the other side is an alternative approach, called here the convergent model, which encourages the diversification of the land use in a mixed matrix (Figure 1). To our knowledge, there is no specific literature that explicitly addresses this subject, nevertheless their properties and functioning characteristics can be inferred from the extensive literature that deals with the intensification of agriculture, food security and biodiversity conservation (e.g. Angelsen & Kaimowitz, 2001; Omer *et al*., 2010; Mather & Nedle, 1998; Perfecto & Vandermeer, 2002, 2008, 2010; Rudel *et al*., 2002; Tenza-Peral *et al*., 2010; Table 1 and Figure 1).

The objectives of this document are: (1) describe the logic behind the divergent and convergent models; (2) compare the two models in terms of their main possible social economical, political and institutional drivers; (3) analyze some of their main consequences for biodiversity, ecosystem services, social and political aspects; (4) compare the agricultural production in both models, and (5) compare the sustainability of the models and highlight the challenges that the convergent model has to face in order to be considered as a serious alternative for sustainable development.

1.-**Divergent and Convergent development models**

The logic behind the divergent model can be illustrated through the Forest Transition Model (FTM), where intensification and clustering of agriculture leads to the industrialization of cities and promotes rural-urban migration. Consequently, marginal rural land is abandoned and prone to forest recovery (Grau & Aidee, 2008; Perfecto & Vandermeer, 2010), which eventually would balance the environmental cost of economic growth. While such process has been documented in the literature for some regions, there is some evidence that the required conditions for it to happen are highly context-dependent and does not comply with the simplistic logic of the model (García-Barrios *et al.,* 2008). As shown in Figure 1, there are several factors that can lead the system into different states, like the expansion of agriculture in abandoned lands or the displacement of rural people into adjacent marginal lands, where they will probably continue their agricultural activities (Kaimowitz & Smith, 2001; Garcia-Barrios *et al*., 2009).

On the other hand, the convergent model could be exemplified by the Quality matrix model (Perfecto & Vandermeer, 2010), where small self-sufficient farmers manage a diversified production through agroecological practices amid a "wildlife friendly" matrix, where species and ecological processes may persist to some extent. Small farmers are not pushed out of their lands, avoiding the mass rural-urban migration and consequently the highly populated cities. However, there are several factors that could act in different parts of the process driving the model into different unpredicted situations, like the high-labor demand that some agroecological systems would require (Figure 1) or the limited access that those farmers have to the global markets where the best prices are (Garcia-Barrios *et al*., 2009).

2.-Social, economical, political and institutional drivers of the models

In the case of the divergent model, policies that promote the intensive use of external inputs in agricultural systems (e.g. those that launched the "Green Revolution") have fostered its development (Angelsen & Kaimowitz, 2001). The main objective of technological advances like the genetically modified crops, the use of chemical fertilizers, pesticides, and fossil fuels in modern agriculture, is to meet the global food demand by increasing yields. Eventually, such intensification would reduce the land demand due to its efficiency, reducing the total area dedicated to agriculture (Smil, 2000). As smallholders, particularly those on marginal lands, would not be able to compete with large-scale producers, rural–urban migration is encouraged (Grau & Aide, 2008; Rudel *et al.*, 2005; Figure 1). This often results in the generation of large urban centers that constitute a positive feedback to this model as they demand an increasing amount of external inputs to persist (food, water, etc; Grimm *et al*., 2008).

Industrialization may represent another important driver for the divergent model. Industry could encourage the depopulation of the countryside as it increase in number and magnitude, attracting rural people looking for jobs and the commodities that cities offer (Grau & Aide 2008; Rudel *et al.*, 2005). The expected consequence of this massive migration is a land sparing phenomenon (Balmford, 2005; Perfecto &Vandermeer, 2008) that releases more land from agriculture.

Strongly market-oriented economies also encourage this development model as they often stimulate the modification of farm inputs and outputs. As such adjustments influence consumer prices and farmers respond to this, monetary cost-benefit considerations become more important for determining land use. “Localization” of high agroindustrial-input agriculture and the ensuing marginalization and abandonment of less-profitable land can occur at local, regional, national, and international levels (García-Barrios *et al*., 2010).

Regarding institutional context, in those countries where a forest transition has occurred, public awareness was a decisive factor (e.g. Ireland, France; Klooster, 2003). As forested lands became depleted in those regions, people suffered scarcity of industrial resources and the disappearance of recreational opportunities. As a consequence of this, the governments created protected natural areas, established forest-management laws, and funded forest-management bureaucracies. Some landowners also began to plant trees and to protect their forests (Klooster, 2003; Mather, 2004). Mather and Needle (1998) suggest that forest transitions may not occur unless governments create effective reforestation programs.

Convergent model, instead, is favored by policies that promote small productive areas where people engage in semi-subsistence activities, sometimes articulated with local or regional markets (Wiersum, 2006; Perfecto & Vandermeer, 2008). The variety of products emerges from a multi-purpose designed area oriented to solve current needs (e.g. food, construction, medicine; Coomes & Ban, 2004; Michon & Mary, 1994). The elements within this productive matrix can change through time because of externalities like the economy (e.g. demand for fresh agricultural products; Michon & Mary, 1994). For example, homegardens in Indonesia have changed over centuries in response to socioeconomic dynamics like urban expansion or changes in the market economy (Michon & Mary, 1994). Traditional gardening is conceived as a low-risk agricultural strategy where gardens act as a secure investment. The variety of products and the multi-purpose dimension reduces economic risk (Michon & Mary 1994). By adapting to new economic activities like fisheries and urban jobs in addition to homegardens, people may get benefits for future generations (Michon & Mary, 1994).

In areas where rural and indigenous population are high, a convergent approach is often promoted by the local stakeholders because they are still acquiring proteins, vitamins and medicines from wild meat, fish and insects; or from wild and cultivated fruits and vegetables (Scoones et al. 1992, Naranjo 2004). Besides, many of the people that lack an adequate access to western medicine rely largely on wild and semi-domesticated plants and animals for much of their medical treatments (Farnsworth & Soejarto, 1991; WHO 2002). These consumption strategies are more related with a high quality matrix (in terms of biodiversity), a characteristic of a convergent model.

3.-Consequences of the models related to biodiversity, ecosystem services, social and political aspects

Divergent models rely in certain assumptions related to the intensification-land sparing argument (Green *et al.*, 2005; Perfecto & Vandermeer, 2008) that are directly linked to biodiversity and ecosystem services (Table 3). Yet, not all these assumptions are met.

It has been assumed that agricultural intensification and land concentration always lead to land sparing (Green *et al.,* 2005; Perfecto & Vandermeer, 2008). Because of their intensification characteristics, this development model tends to overexploitation of natural resources, affecting the ecological aspects by improving habitat homogenization and degradation in some areas, but restoration activities and conservation somewhere else (Rudel 1998, Angelsen & Kaimowitz 2001). Agriculture intensification generates more profits and may act as a driver for increasing economic activities, which in turn creates a higher demand for goods and services, immigration, and potential higher deforestation rates (Wiersum, 1986; Angelsen & Kaimowitz, 2001; Morton *et al*., 2006). For example, Brazil currently leads the production and exporting of soybean, sugar, coffee, oranges, poultry, beef and ethanol (FAO Yearbook, 2008). Most of the explanation for such agricultural success is related to increased yields and the expansion of the areas dedicated to exporting crops. As a consequence, this process has been accompanied by massive deforestation in three major forest biomes: the Atlantic Forest, the Cerrado, and the Amazon Forest (Martinelli, *et al.*, 2010 in press). A similar pattern has been observed in Bolivia, Paraguay, Argentina, Cameroon and Indonesia (Grau & Aide 2008; Rudel et al., 2005).

The intensification process may also result in the displacement of small farmers, which according to the logic of the model, represents a driver for the massive urban immigration. What has been observed is that people sometimes prefer to move to adjacent lands, expanding the agricultural frontier and causing the associated deforestation phenomenon (Kaimowitz & Smith, 2001 Garcia-Barrios et al. 2009). In southern Brazil, the decrease of labour demand associated to the new soybean technologies has derived in the displacement of existing peasants, and some of them had moved into new lands (Kaimowitz & Smith, 2001).

Even if land sparing is accomplished, natural vegetation regeneration may be insufficient or become stagnated, and that situation would demand large amounts of energy and knowledge to reach a full recovery of the natural vegetation. In a meta-analysis of restoration ecology, Benayas and coworkers (2009) showed that measurements of biodiversity and ecosystem services (i.e. supporting and regulating types according to the MEA) were higher in restored than in degraded systems, but lower than reference systems.

It has also been assumed that there is a trade-off between maintenance of biodiversity in farmlands and yield increments (Green *et al*., 2005). This perception has derived in the implementation of compensation schemes for production losses in some agroecological systems (Green *et al*., 2005). This assumption may be valid for the industrialized agricultural systems, especially for those that implement technologies derived from the “Green Revolution”, but not necessarily in more complex agricultural systems.

For example, in a meta analysis of 208 projects on 52 developing countries, Pretty and coworkers (2003) demonstrated that farmers achieved great improvements in food production mainly by the implementation of sustainable practices like intercropping and some others related to soil health and fertility (through the use of legumes, fertilization through organic manure, etc). This combined practices increased the heterogeneity and complexity of the agricultural system at different temporal and spatial scales (Benton *et al*., 2003; Norton *et al*., 2009), which may help to reverse the declining trends in farmland biodiversity (Hole *et al.*, 2005).

Even if the relationship between agricultural intensification and changes in biodiversity is not clear (Perfecto & Vandermeer, 2008), some evidence suggest that it is the type of agriculture what influences the maintenance of biodiversity**.** The correlation observed between songbirds populations decline in some areas of the United States and the transformation of coffee systems in Central America illustrates this point.

In the Millennium Ecosystem Assessment (MEA, 2005) the Global Orchestration scenario[i] represents a divergent pattern, where there is an improvement related to the so called provision services, but the regulation and cultural services are generally degraded with differences between the developing and the industrial countries (Table 3).

It has been assumed that in the convergent model a matrix of non-intensive diversified agriculture and forested areas can maintain biodiversity (as shown in figure 1). For example, traditional coffee production in Central America is carried out in shadow agricultural systems that allow the persistence of a diverse assemblage of trees (Perfecto *et al*., 1996). These coffee systems are important winter habitats for migrant birds from North America (Greenberg *et al*., 1997; Tejeda-Cruz & Sutherland, 2004). This information has been important for demonstrating that agricultural ecosystems can be critical repositories of biodiversity (Perfecto *et al*., 2003; Moguel & Toledo, 1999). However, the amount or type of biodiversity that non-intensive diversified agriculture sustains is often different from the adjacent forests. Kehlenbeck & Maass (2004) report a different spectrum of species cultivated in homegardens in three villages in Sulawesi, with Sørensen coefficients ranging from 61% to 74%. In shaded cocoa systems some taxa show similar levels of diversity when compared to the adjacent forests (Perfecto & Vandermeer, 2002; Bos *et al*., 2007;

Delabie *et al*., 2007). In other cases the diversity is similar but the species composition differs, which highlights the importance of maintaining a mosaic of land-use systems, including forests for the conservation of the highest levels of biodiversity (Bos et al., 2007).

A common practice in convergent models that could lead to negative impacts in biodiversity is the use of biocontrol agents, as they often are comprised of non-native fauna used to control noxious weeds or pests. DePrenger-Levin and coworkers (2010) shown the negative effects that an introduced weevil (*Rhinocyllus conicus* Frölich) had on a rare and native thistle (*Cirsium ownbeyi* S.L. Welsh) in parts of Colorado, Utah and Wyoming (USA). Even when the weevil apparently has no effects on the population size of *C. ownbeyi* in the short term, they limit population growth. The combination of population fluctuations of the thistle and a steady amount of damage by the biocontrol put the long-term viability of the C. ownbeyi at risk (DePrenger-Levin et al., 2010).

From the MEA perspective, the convergent model is viewed as the Adapting Mosaic[ii] scenario (MEA 2005; Alcamo *et al*. 2005) where the three types of services: provision, regulation and cultural are predominantly improved. Yet, this pattern is not global, and there are differences among the industrial and developing countries (Table 3).

Also the social and political aspects are affected in different ways depending on the predominant model, but there is a lack of empiric studies that could illustrate those phenomena (Table 3). In the divergent model, effects on culture (viewed as instincts, rituals, traditions, and costumes) are commonly ignored, so part of cultural knowledge tends to be displaced and lost (MEA 2005, Michon & Mary, 1994, Coomes & Ban, 2004; Perfecto & Vandermeer 2008). In other aspects related to human and social well-being, like a long and healthy human life, education, and life standards presumably increases with the divergent model, especially in industrialized regions, but it is still a debated point (MEA 2005, Perfecto & Vandermeer 2008). Usually, other aspects like love/belonging, self-steem, and self-actualization (*sensu* Maslow pyramid; Grow, 1991) are not considered, and this constitutes a vibrant subject for debate (this seminary itself).

In contrast, culture can be preserved in the convergent model (Atran et al. 1993; Michon & Mary, 1994, Coomes & Ban, 2004; Perfecto & Vandermeer 2008). Also, social conflicts related to equity and social justice can be decreased or increased depending on the specific situation (Grau & Aide 2008, Perfecto & Vandermeer 2008, García-Barrios et al. 2010).

4.-Agricultural production and local/global demand under the divergent and convergent models

Divergent and convergent models can be associated with two opposite types of agricultural production. The divergent model is focused on large producers oriented to global markets, that require an intensified farming, involving a high demand of external inputs (chemicals, pesticides), high levels of contamination, high emissions of C due to transport their products to international markets, genetically improved crop varieties, among others. The convergent model would consist of small producers mainly aimed at supplying local and regional markets, their production volumes are modest and with a limited use of external inputs or none at all (Perfecto & Vandermeer 2008).

The intensive agriculture demand of inputs jeopardizes the viability and preservation of the natural systems that underpin the functioning of agricultural systems (soil, water, nutrients). Agro-ecological systems (Convergent) point to the elimination of polluting inputs and those that threaten biodiversity, and give more to the quality of the products that the quantity produced, although many authors discuss whether these systems can support food production with the actual demand.

The proposition that organic agriculture can contribute significantly to the global food supply are low yields and insufficient quantities of organically acceptable fertilizers. Badgley *et al.* (2007) compared yields of organic vs. conventional or low-intensive food production for a global dataset of 293 examples and estimated the average yield ratio (organic:non-organic) of different food categories for the developed and the developing world. They modeled the global food supply that could be grown organically on an agricultural land base. Model estimates indicate that organic methods could produce enough food on a global *per capita* basis to sustain the current human population, and potentially an even larger population, without increasing the agricultural land base.

5.-Conclusions

Based on the data above, we consider the convergent model as a more sustainable approach that permits the persistence of some forest elements in the agricultural field and their associated wildlife within the matrix (Perfecto & Vandermeer, 2010). This model could limit the depopulation of rural sites and maintain medium sized cities that could assume some production responsibilities (Cuba is a good example, where urban production in 1996 reached 8500 tons of agricultural producs; Altieri *et al*., 1999).

On the other side, as expressed by some researchers (Perfecto personal communication), the divergent model, as currently practiced, is not a viable option for sustainability. Some measures could be implemented to make this model more “biodiversity friendly”: cities could change its role of “sinks” and assume some degree of production; agricultural lands could change part of their pesticides and fertilizers inputs for biological ones (Omer *et al*., 2010).

Based on the above discussion, we identified some challenges and recommendations in sustainable science for the convergent model.

1. Limit the transition of convergent models into divergent ones. This has been done in a relatively fast and easy way through a high use of external inputs. About the opposite conversion, we could face states of “divergent traps” that are difficult to overcome.
2. Promote research to strengthen convergent models, exploring the role of access to major markets, and how to deal with intolerance from farmers to native fauna and the intensive labor that some convergent systems require.
3. Promote research to encourage the conversion from divergent to convergent models.
4. Exploring the dynamics and consequences for the social and ecological systems under convergent and divergent models.
5. Promote interdisciplinary participation is needed. For example, cognitive sciences, are important for the understanding of making decisions in the economic contexts, so they can help in promoting convergent model in different socio-environmental systems.

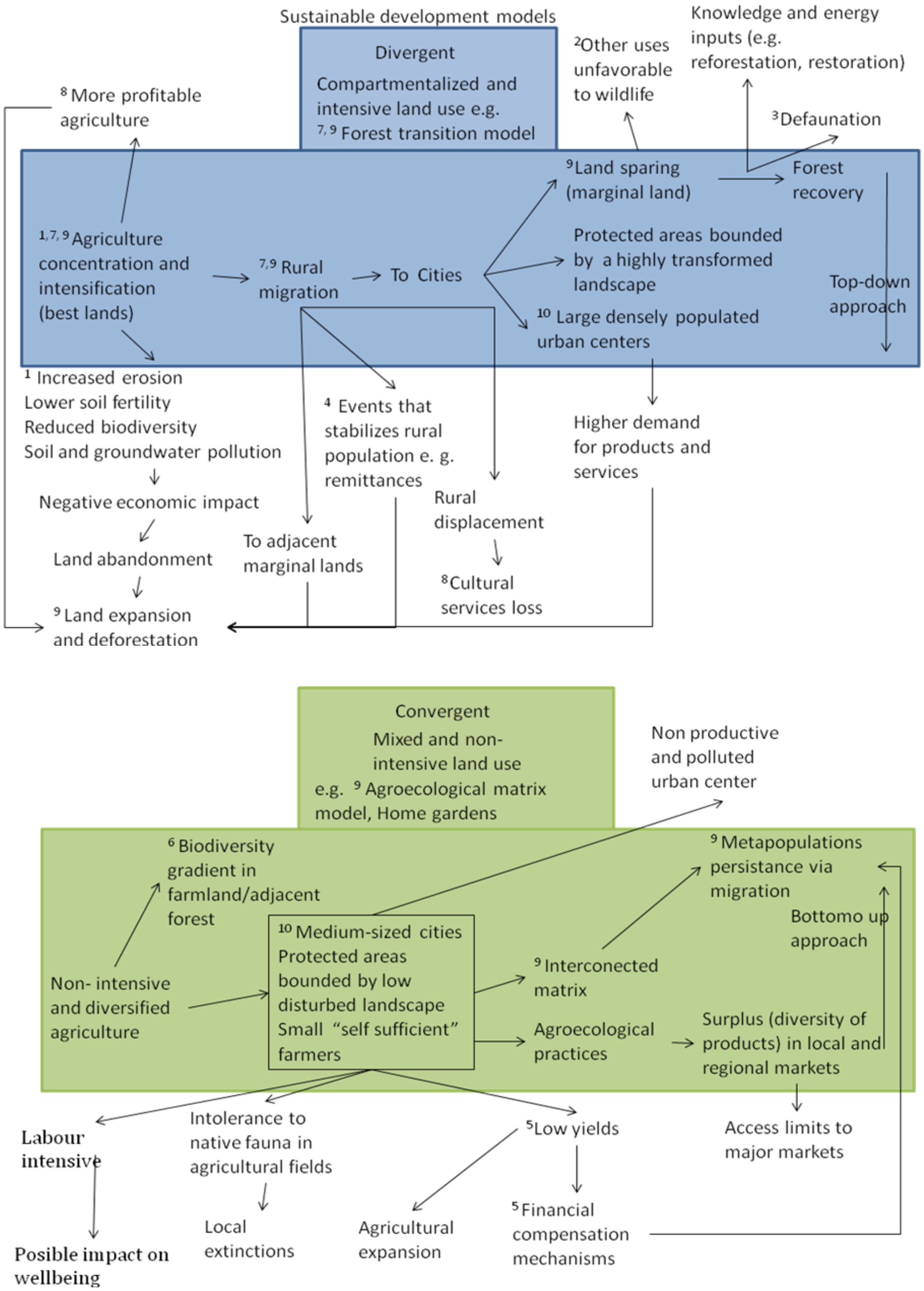

Figure 1. Mechanisms of divergent and convergent models. Inside the rectangles are the general logic arguments of the models. The outside arrows and text are factors that can drive the mechanism into a different direction. Figures were produced based on [1]Angelsen & Kaimowitz 2001; [2]Balmford 2005; [3] Dirzo & Miranda; [4] García-Barrios et al, 2010; 5 Green et al. 2005; [6] Kehlenbeck & Maass, 2004; [7] Mather et al., 1998, 2008; [8] MEA 2005; [9] Perfecto & Vandemeer 2008, 2010; [10] Tenza-Peral et al., 2010).

Table 1. Main characteristics of the divergent and convergent models.

Divergent Model	Convergent Model
Strict division of land use (e.g. best lands for intensive agriculture, marginal land for forest recovery)	Matrix. Agriculture, cattle and forest combined.
Large cities highly populated	Medium-size cities not highly populated
Concentration of rural population in areas of intensive agricultural production	Scattered and isolated rural areas
High external input Intensification (technology, energy consumption) of agricultural production with monocultures	Non intensive and diversified agriculture
Mass production of food, with access of major markets	Small self-sufficient farmers for local consumption with surplus in regional markets
Vulnerable to disturbances. Connectivity between habitats null	Resistant to some disturbances by the interconnection between habitats
Local extinction of various species in agricultural fields	Local extinctions of some non-tolerant species

Modified from Tenza-Peral *et al.*, 2010.

Table 2. Factors that could favor divergent and convergent models (from Bongaarts Turner Kates, Chapter 1.2, DRAFT in Sustainability Science; MEA 2005; Perfecto & Vandermeer 2008, and Ostrom & Nagendra 2006).

Divergent Model	**Convergent Model**
Large population size	-
High population densities	Low population densities
State governance International governance Corporations	Communal governance Independent or autonomous governance State governance? [17, 21]
Interventionists	?
Exportation and marketing the product (Rudel?)	Direct use of the product [1, 33]
International market	Local and Regional market
Technology and scientific development	Traditional Ecological Knowledge (TEK) [3, 9, 32, 44].
High energy availability	---?
Social inequity?	Social equity? [14, 18, 44, 56]

Table 3. Consequences of the divergent and convergent models on the ecology, ecosystem services, and the social and political aspects.

Aspects	Divergent Model	Convergent Model
Biodiversity	Habitat homogenization, lost, restoration and conservation in different parts.[48]	Habitat conservation and restoration in some parts; and alteration in others.[48]
	Biodiversity varies from place to place.[49]	Mainly biodiversity conservation, but in some parts alteration and lost. Debatable according to studies in landscape structure and corridors.[17, 21]
	Invasive species and competition present and absent depending on the place and situation. [10, 17, 21.]	Invasive species, and competition present and absent. Debatable according to studies in landscape structure and corridors. [10, 17, 21, 52.]
Ecosystem services	Provision ecosystem services improved (more in developing countries than in the industrial ones; viewed as Global Orchestration).[1, 33]	Provision services improved (more in industrial countries than in the developing ones; viewed as Adapting mosaic).[1, 33]
	Regulating ecosystem services degraded (more in developing countries than in the industrial ones; viewed as Global Orchestration).[1, 33]	Regulating ecosystem services improved (more in developing countries than in the industrial ones; viewed as Adapting mosaic).[1, 33]
	Cultural ecosystem services degraded (more in industrial countries than in the developing ones; viewed as Global Orchestration).[1, 33]	Cultural ecosystem services improved equally in the both industrial and developing countries (viewed as Adapting Mosaic).[1, 33]
Social and political	Culture (e.g. Traditional Ecological Knowledge; TEK) lost due displacement.[9, 32, 33, 44]	Culture (e.g. Traditional Ecological Knowledge; TEK) conserved[3, 9, 32, 44].
	Social conflicts related to equity and social justice increasing (e.g. Social deterioration, forced displacement in the REBIMA).[8, 18, 44]	Decreasing social conflicts like equity and social justice[14, 18, 44, 56]
	Long and healthy human life debatable.[47]	Long and healthy human life debatable.[47]
	Education presumably increasing.[47]	Education not tested and debatable.[47]
	Life level presumably increasing (GDP).[47]	Life level debatable (GDP). [44, 47]
	Love/belonging, esteem and self actualization (Maslow pyramid) not evaluated.	Love/belonging, esteem and self actualization (Maslow pyramid) not evaluated.
	Ability to respond to socioeconomic changes not evaluated.	Ability to respond to socioeconomic changes until certain point.[59]

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[i] Global Orchestration: Globally connected society that focuses on global trade and economic liberalization. Takes a reactive approach to ecosystem problems, but also takes strong steps to reduce poverty and inequality and to invest in public goods, such as infrastructure and education (Alcamo et al. 2005).

[ii] Adaptive Mosaic: Regional watershed-scale ecosystems are the focus of political and economic activity. Local institutions are strengthened and local ecosystem management strategies are common; societies develop a strongly proactive approach to the management of ecosystems (Alcamo et al. 2005).