GEOG 211

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Geography 211

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Dynamics of Arable Land Crisis: Understanding the Intertwined Predicament of Population and Environment

When we say - "arable land" what people imagine?

The question is critical in this age because human wellness increasingly depends on how sustainably we produce foods (Myer 609); population will grow at least 9 billion people in 2050 and how to support that many of people sustainably depends on “green revolution” which is an approach that Britain's Royal Society aptly describes as the "sustainable intensification of global agriculture" (Nature). However, in actuality, we are conducting unsustainable short-term yield maximizing agriculture around the globe and heading to long term catastrophe. In the article *Safe Operating Space for Humanity*, Johan Rockström and his colleague assessed nine global environmental issues and see if we are within the "safe operating space" (472). According to their study, modern civilizations have significantly altered nitrogen cycle that the soil degradation is beyond the threshold. Therefore, arable land crisis is one of the most severe issue that human face now. In fact, throughout history, great civilizations perished because of land degradation stemmed out from land use change (Redman 152), such that is identical to what we see today globally. Therefore, the discourse of sustainable arable land needs to develop for continuity of humankind. In this research, by employing the UN representation model called DPSIR (Driver Pressure State Impact Response), the relationship between socio-economic needs and ecological consequences will be analyzed. Lastly, I will analyze potential ways to mitigate the impact of climate change for arable land, providing active participation approaches for industries, policy makers and individuals.

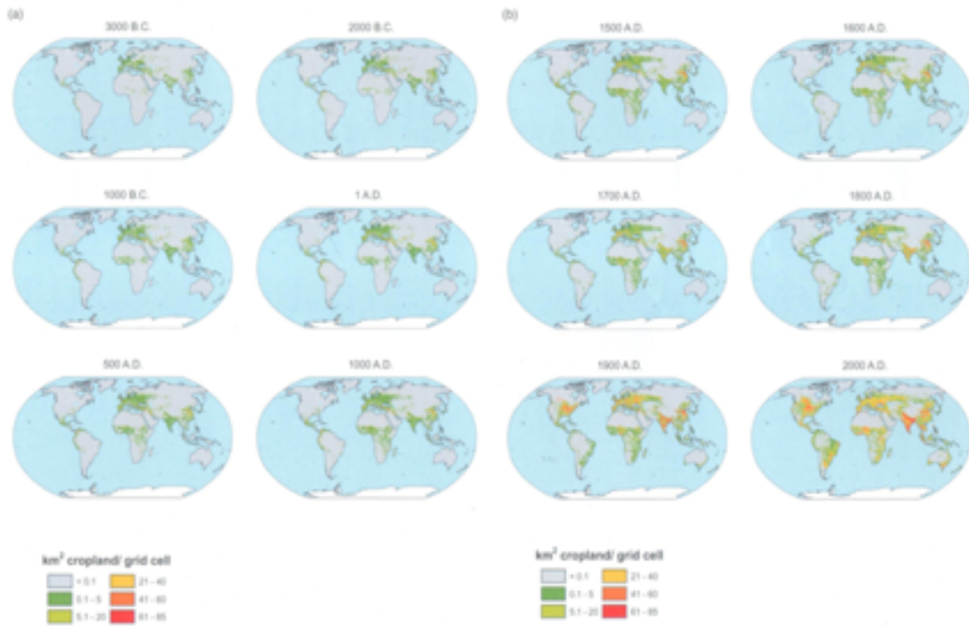
Arable land framework

Arable land is not an issue only with farmers. Yet, multidimensional factors play roles to develop arable land crisis. Land use change, soil quality, population growth, economic mode, climate change, water mismanagement and individual dietary choice constitute major components of this crisis (Myers 610). Although many more issues surrounding arable land such as biodiversity loss and greenhouse gas emission, they are issues which stemmed out of the system dynamics, so they are outcome and not a wheel driving the crisis. Therefore, this research will focus on the driver of arable land crisis with the inclusive paradigm.

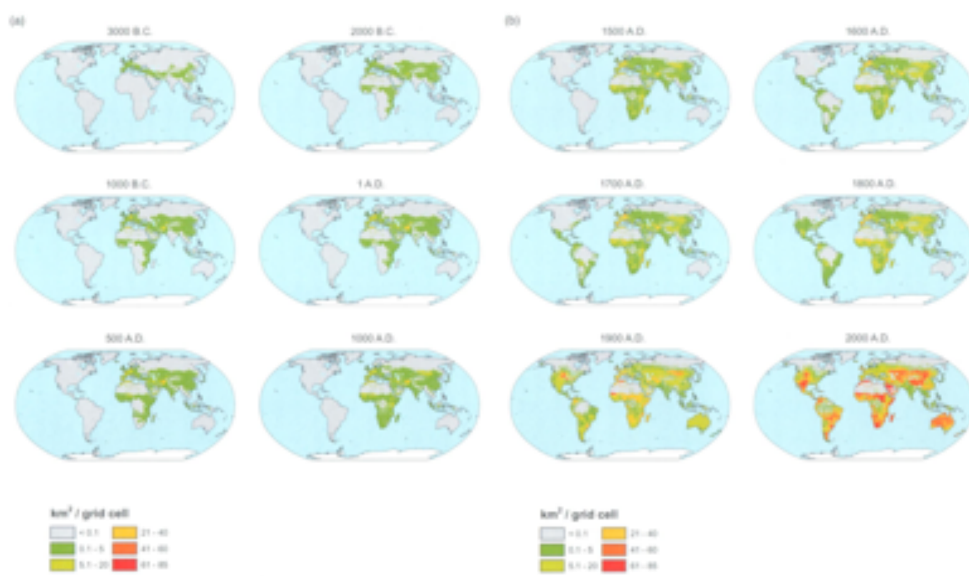
Dynamics and History

In 10,000 BC, cultivation of staple crops and domestication of animals started mainly in Eurasia and Africa. This global phenomenon, which we call the first agricultural revolution granted breakthroughs for civilizations, partly because the emergence of agriculture created the wealth that can be produced and also reserved (Myer 611). In other words, it allowed "surplus" to exist for the very first time in human history. The emergence of surplus gave rise to wealth inequality between people and developed power structure within society. Furthermore, it allowed society to afford militaries, and produce other commodities with specialization of labour which all contributed to a more stable economy (Smith). However, because of population growth, diminishing return for each person become prevalent; eventually, with a predetermined area of land, we can only produce a statistic amount of foods. Meanwhile, the number of consumers increase exponentially every year - this is the famous Malthusian theory. This paradox is the essential origin of wars, famine and environmental degradations where pressured leaders decide to invade and expand for their sake. Some civilizations such as Mesopotamia, Maya and Hohokam perished by knowingly or unknowingly invading another entity - nature. Redman summarizes the cause of collapses for these ancient civilizations as destabilization of grounding ecosystem which stemmed out from land use change. In other words, salinization, deforestation, and soil erosion that led the collapse of the great civilizations were majorly caused "through excessive agricultural practices" (Redman 151). Therefore, continuity of civilizations, population growth and environmental degradations are intimately connected.

Secondly, the historical expansion of arable land and population growth coincides; however, there is virtually no available agricultural land to support additional 3 billion people. Goldewijk et al. studied global population size and change in land cover from the dawn of mankind and constructed "historical maps of cropland and pasture for a 12,000-year period" (79). According to the researchers, an important point in history took place in the 1600s when the industrial revolution allowed Europeans to colonize the Americas, Australia and Africa (80). This is because colonization triggered the rapid land-use change globally; in the Americas which previously had no pasture, Europeans imposed sizable grazing, and for cropland, the global total area "almost doubled every century after the 16th from 3 million km2 in AD 1700 to 4.2 million km2 in AD 1800, 8.5 million km2 in AD 1900 and 15.3 million km2 in AD 2000" (Goldewijk et al., 80). Meanwhile from 1600 to 2000, population has increased 11 times; from 554 million global population in 1600, 603 million in 1700, in 1800 to 989 million, in 1900 to 1.6 billion, in 1950 to 2.5 billion and 2000 to 6.1 billion (Goldewijk et al., 77). Therefore, unprecedented land cover change happened at a global scale from the industrial revolution era as to support population growth. Notwithstanding this historical positive correlation, currently, agriculturally optimal lands are already in use and supporting additional 3 billion people from nearly same acres of arable lands is a predicament humankind never faced before (80).



These series of map represent historical cropland area (Goldewijk et al. 76).



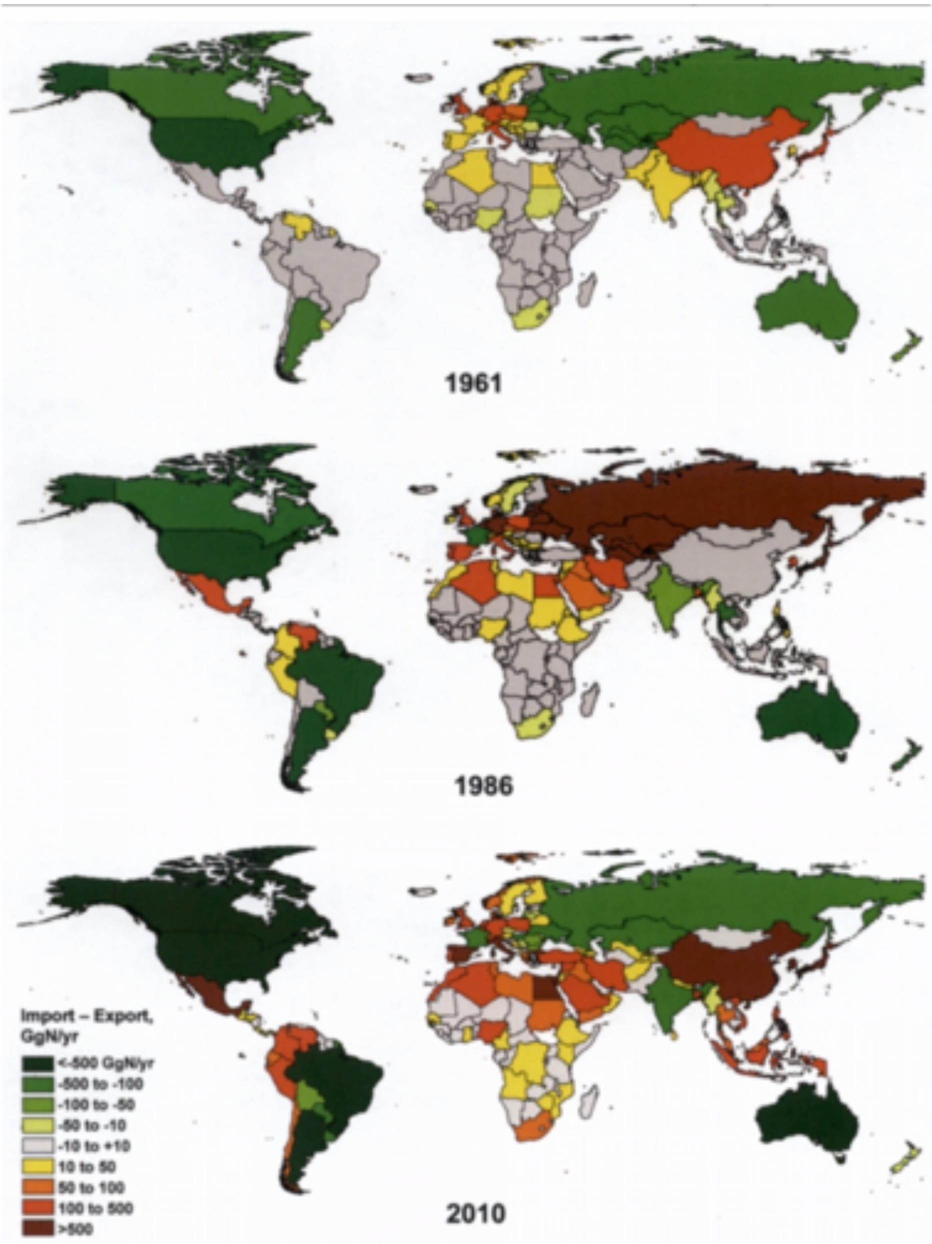
These series of map represent historical pasture area (Goldewijk et al. 77)

Driver and Pressure: Global Capitalism

The arable land crisis is both "cause and consequence of biophysical and socioeconomic processes" (Assellen and Verburg 3648), and to understand the drivers of the catastrophe, a close investigation into the socioeconomic model is necessary because our highly globalized and market-based economy can shape the crisis moreover.

First, world trade significantly alters global Nitrogen cycle, causing many environmental stresses; Lassaletta et al., researched "nitrogen content of all the agricultural products (food, feed and fibres) traded between all world countries during the last 50 years" (227) from 1961 to 2010. According to their finding, during the period, the exchange of agricultural products increased more than ten times (234), and the pictures revealed that a world divided into a small number of countries of net exporting regions such as North America and South American Soy countries. To explain this point, relatively wealthy regions such as Europe, and East Asia imports more nitrogen from net export countries, often in the form of feed, in order to specialize their production in livestock farming (237). Meanwhile, net export countries often bear the environmental consequences such as air and water pollution, loss of soil fertility and erosion, GHG emission, water and land grabbing, loss of biodiversity and deforestation from the intensified mode of agriculture (238); the net exporters "have developed large scale areas of intensive crop farming completely disconnected from livestock breeding" which uncoupled C and N and increasing the "N losses through leaching and denitrification" (237). For example, corn belt within the Mississippi river basin where they produce most of US N exports, this mechanism of nitrogen spillover is driving the eutrophication of the Gulf of Mexico (Selman). Accordingly, world trade allows to distance environmental impacts from where the product is consumed. In addition, the areal specialization of agriculture for meeting global demand is stressing the environment.

Figure 2: These maps are representing net import or export of virtual nitrogen in a country through history from 1961 to 2010. Darker colour represents export (Lassaletta el al. 236).



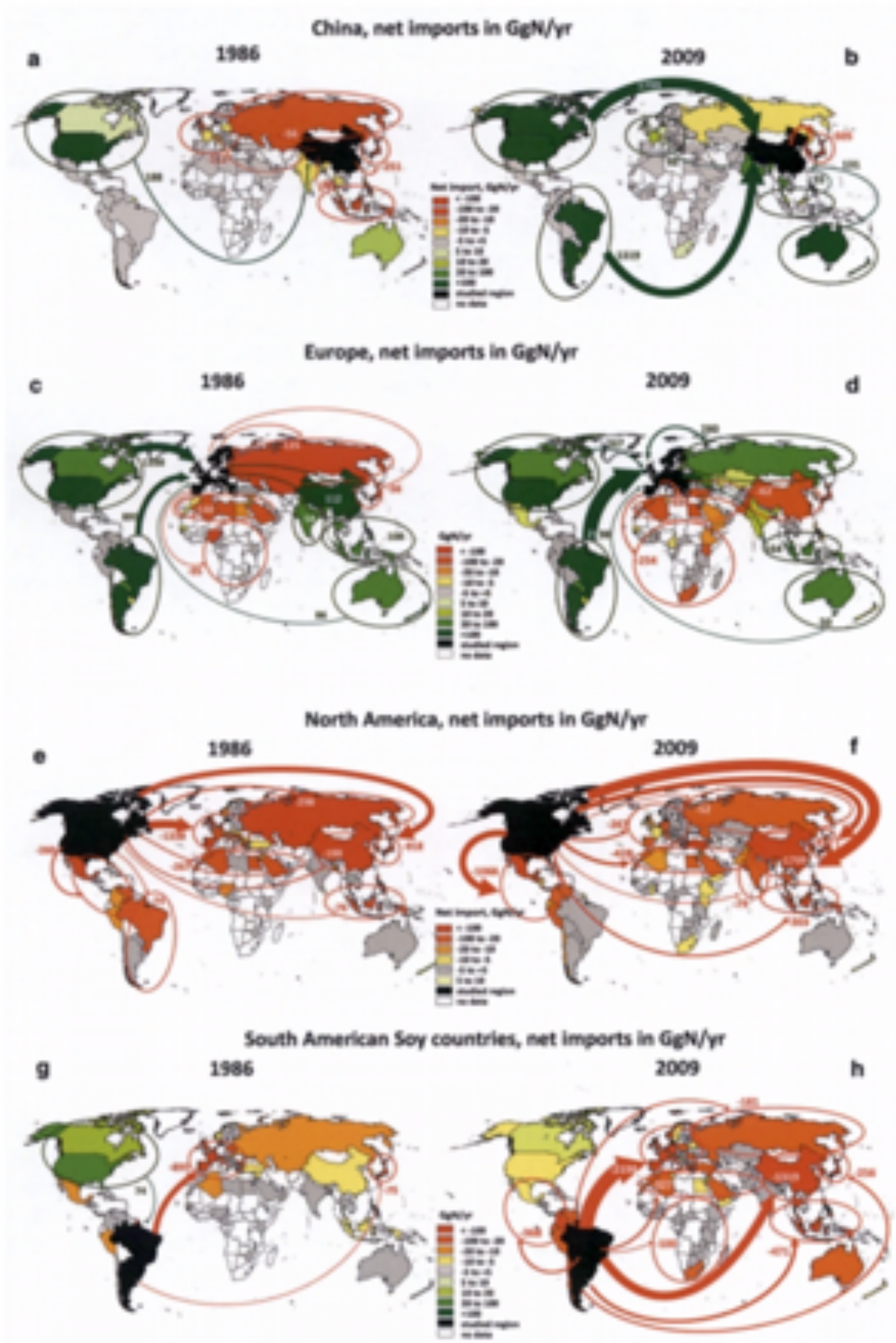


Figure 3: These series of maps represent net imports of nitrogen by each region and where they get the net balance from. Also, the colour of allow illustrates if the region is exporting or net importing: red and green respectively (Lassaletta et al. 238).

Second, the failure of capitalism to account externality for environmental degradation is driving the crisis by large (Lassaletta et al., 232). In other words, corporations can bear the cost down to nature in order to maximize their profit. For example, despite deforestation of Amazon forest would terminate the most biodiverse ecosystem in the world, cattle ranching industry is managing to expand and making a profit (Yale). It is economically attractive because of accessible transportation in rural areas, low yields and cheap land in the Amazon region. These conditions encourage unprecedented expansion and deforestation. Currently, 450,000km2 of Amazon forest have been deforested for this reason (Yale).

Lastly, economic policies such as neoliberalism shape the course of global trade and arable land dynamics by large. Naomi Klein explains how neoliberalism policy in the 1980s scaled up intensity and quantity of world trade (Klein). Also, such ideological politics lead mega-corporations to privatize seeds as intellectual property and dominate the market as Monsanto dominates 23% of the world's seeds market (Eliot 639).

State: Soil Degradations and Water Scarcity

Dynamics of arable land changes the state of the earth by large, mainly, we cause inimical soil degradations and water scarcity. First, soil degradations issue is as severe as climate change and biodiversity loss that they both exceed planetary boundaries (Rockström 472); land degradation affects approximately 25% of the global land area in the form of physical, chemical, biological and ecological impairments of soil or surrounding ecosystems (Webb et al., 450). Furthermore, it is estimated that 40% of such land degradation takes place in developing countries where population growth is high (451), and also because land degradation is especially prevalent among tropics and subtropics (Lal 5876). In this regard, Lal informs us the importance of soil quality that these land degradations have the origin in degradation of soil structure (5877) and it can magnify by "the downward spiral of decline in soil and environment quality" (figure 4, 5877). Prevalence of degraded soils in sub-Saharan Africa is a typical example of this spiral; "overexploitation, extractive farming, low external inputs, and poor or improper management" (5879) shaped the crisis first, and subsequent political instability followed. Accordingly, soil quality deterioration is the base and primary source of the arable land crisis, and it is estimated that 33% of all soils are degraded (5888). To improve soil quality, Lal argues that monitoring through Soil Organic Carbon (SOC) pool is the most reliable method to assess and tell where to put effort into (5878). In addition to the content of organic carbon, other measures of SOC include "it depth distribution, quality or attributes and the turnover rate or the mean residence time" (58880).

Figure 4: “The downward spiral of decline in soil and environment quality exacerbated by indiscriminate plowing, residue removal and extractive farming” (Lal 5877).

Second, the dynamics of arable land crisis is escalating water scarcity issue. That is to say significant concerns of water security - depletion of aquifers, decreased water availability among snow dominated river region and significant alteration of hydrogen cycle caused by dams all have the origin in population growth, economic structure and current agricultural practice. To explain this point furthermore, despite "one-sixth of the world's population lives within snowmelt- dominated, the low-reservoir-storage domain" (Barnett et al. 304), warming climate effects such as early seasonal runoff, less snow accumulation and longer dry season will impact them with the crisis of water shortage (306). Moreover, alteration of hydrological cycle by dams threatens river biodiversity severely as well as leading to human water insecurity (Davis et al., 556). Lastly, this is a global phenomenon where most of the agricultural regions are affected (Figure 5).

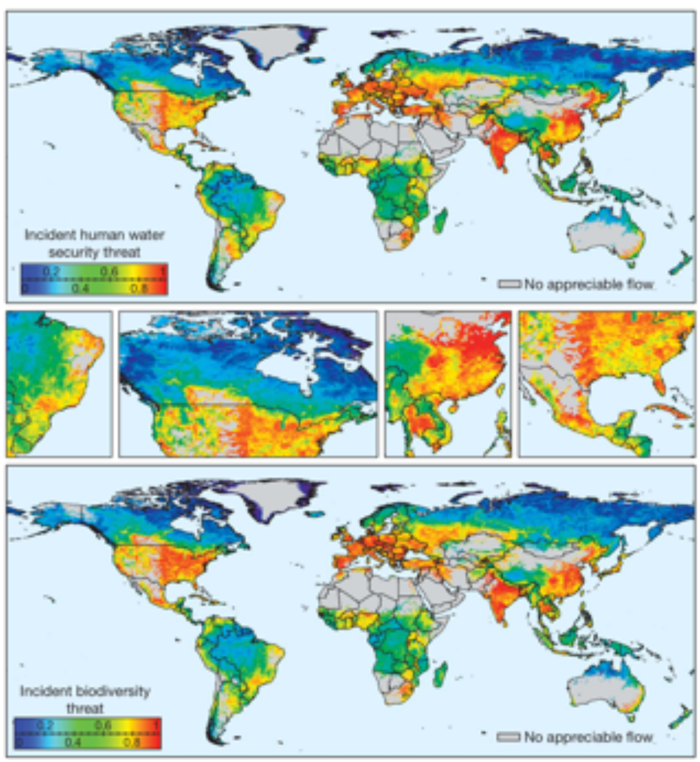


Figure 5: Global geography of incident to human water security and biodiversity (Davies et al. 557)

Impact: Carrying Capacity and Depletion of Aquifer

Although excessive resource usages and unsustainable practices may result in higher productivity for the short term, the prolonged consequences can abruptly emerge to devastate society. For example, in Saudi Arabia, between 2007- 2010 wheat production dropped by more than two thirds, and in 2012 they became entirely dependent on import to feed 30 million people (World Food Security 53). This is because they used aquifer to grow wheat more than the replenishing rate for more than 20 years and it virtually dissipated (54). In this example, the depletion of water table in Saudi Arabia represents carrying capacity shift; they operated way beyond the environmental threshold and subsequently, carrying capacity of the environment plummeted to find a new equilibrium point. In this case, the new equilibrium point is no groundwater and thus no production capability of crops. Accordingly, operating beyond the natural threshold can enhance our production for a short period but prolonged consequences that accumulated over the years can burst at some point to impact humanity. This "food bubble" are estimated to affect half the world population as they face a falling water table and depleting aquifer (53).

Response: For Policymakers and Industries

For people who stewardship society, I recommend implementing Conservation Agriculture (CA) policies which predominantly focus on sustainable soil and water management. This is because the dynamics of arable land crisis is composed of the failure of preserving these two elements fundamentally. According to Lal, soil quality not only acts as the birth of catastrophe, if it recovers by efforts, but it also leads to socio-economical and physio-environmental positive chain reactions (Figure 6). Additionally, he states CA is principally composed of 4 practices: "(i) retention of crop residue mulch; (ii) incorporation of a cover crop in the rotation cycle; (iii) use of Integrated Nutrients Managements (INM) involving combination of chemical and biofertilizers; and (iv) elimination of soil mechanical disturbances" (5880). To pragmatically implement these measures, for example, reducing the amount of fertilizer and pesticide used for arable land (Lechenet et al., 9), and implementing "holistic managements" advocated by Allon Savory to combat desertification where livestock mimic the migration pattern of wild animals to restore the cycle of the ecosystem are practical and significant approaches. Therefore, these are primary tactics to address the arable land crisis, even though they are not quick-fix but rather need long term dedication, indicators such as SOC help monitoring and assessing the state of arable land.

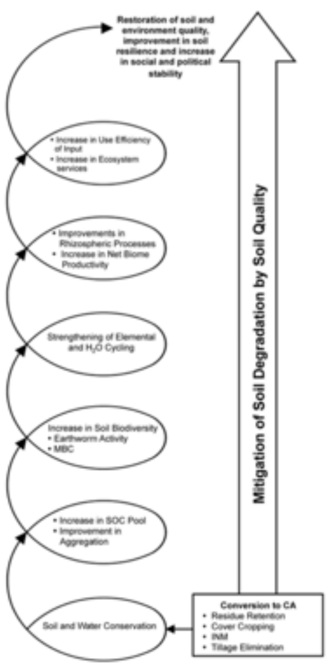


Figure 6:

Positive chain reaction diagram: “increase in soil resilience and mitigation of soil degradation by conservation agriculture” (Lal 5881).

For Individual – Dietary Choice

Individual diet constitutes the driver of arable land crisis, and effective allocation of agricultural resource is key to sustainability. Bahadur et al. explored "the extent to which global food production was nutritionally sufficient for 2011 (when the world's population was approximately 7 billion) and will be sufficient for a population of 9.8 billion, which is expected in 2050" (2). In this study, they used the Harvard Healthy Eating Plate (HHEP) nutritional model guidelines to compare with current statistics to estimate the impacts on land use and greenhouse gas emissions (Table 2 and 3). According to their study, if global food production aligns with HHEP, grain production, fat and oil production and sugar production should drop by 150, 105, 30 million ha respectively; however, on the other hand, vegetables and fruits production, livestock feed, and plant protein have to increase 171, 57, and 20 million ha respectively. Therefore overall, we can expect to "reduce the amount of arable land needed for agriculture by a total of 51 million ha" (6), if we follow the healthy eating habit societally. This research indicates the mismatch to warn the significance of individual diet to shape the sustainable arable land; in other words, sustainable agriculture comes from healthy eating.

Table 2. Land area (in million ha) using FAO data, assuming universal adoption of the Harvard Healthy Eating Plate (HHEP) nutritional guidelines for 7 billion people (today) and 9.8 billion people (projected for 2050) assuming that the yields of all crops continue to grow by 1%/year following historic trends. Percentage change from current values is given for alternative scenarios in parentheses.

Food groups	**Without adoption of HHEP (existing diet)**		**With adoption of HHEP diet**					
			Existing ratio of protein from livestock and plants		**20% Protein from animal sources and 80% protein from plants sources**		**Protein from plants only**	
	For 7 billion (FAO data today)	**For 9.8 billion (2050)**	**For 7 billion (today)**	**For 9.8 billion (2050)**	**For 7 billion (today)**	**For 9.8 billion (2050)**	**For 7 billion (today)**	**For 9.8 billion (2050)**
Whole grains	407	411	257 (-37%)	260 (-36%)	257 (-37%)	260 (-36%)	257 (-37%)	260 (-36%)
Fruits & Vegetables	89	90	260 (+192%)	263 (+196%)	260 (+192%)	263 (+196%)	260 (+192%)	263 (+196%)
Oils & Fat	153	155	48 (-69%)	49 (-68%)	48 (-69%)	49 (-68%)	48 (-69%)	49 (-68%)
Livestock Protein	103	104	160 (+55%)	162 (+57)	39 (-62%)	40 (-61%)	0	0
Plant Protein	36	37	56 (+56%)	57 (+58)	267 (+642%)	270 (+650%)	334 (+828%)	338 (+839%)
Milk/dairy	220	222	206 (-6%)	208 (-5%)	206 (-6%)	209 (-5%)	206 (-6%)	208 (-5%)
Sugar	30	31	0	0	0	0	0	0
Arable land Total	**1038**	**1050 (+1%)**	**987 (-5%)**	**999 (-4%)**	**1077 (+4%)**	**1091 (+5%)**	**1104 (+6%)**	**1118 (+8%)**
Pastureland for Meat	1092	1529	1699 (+56%)	2377 (+118)	409 (-63%)	573 (-48%)	0	0
Pastureland for Milk/dairy	2341	3277	2192 (-6%)	3073 (+31%)	2192 (-6%)	3069 (+31%)	2192 (-6%)	3073 (+31%)
Pastureland total	**3433**	**4806 (+40%)**	**3891 (+13%)**	**5450 (+59%)**	**2601 (-24%)**	**3642 (+6%)**	**2192 (-36%)**	**3073 (-10%)**
Grand total	**4471**	**5856 (+31%)**	**4878 (9%)**	**6449 (+44%)**	**3678 (-18%)**	**4733 (+6%)**	**3296 (-26%)**	**4191 (-6%)**

Table 3. Greenhouse gas emissions (GT CO2e/yr) using FAO data, assuming universal adoption of the Harvard Healthy Eating Plate (HHEP) nutritional guidelines for 7 billion people (today) and 9.8 billion people (projected for 2050). Percentage changes from the current values are given for both alternative scenarios in parentheses.

Food groups	**Without adoption of HHEP (Existing diet)**		**With adoption of HHEP diet**			
			Existing ratio of protein from livestock and plants		**Protein from plants only**	
	For 7 billion (FAO data today)	**For 9.8 billion (2050)**	**For 7 billion (today)**	**For 9.8 billion (2050)**	**For 7 billion (today)**	**For 9.8 billion (2050)**
Whole grains	0.88	1.24	0.54 (-39%)	0.76 (-14%)	0.54 (-39%)	0.75 (-15%)
Fruits & Vegetables	0.32	0.44	0.58 (+81%)	0.82 (+156%)	0.58 (+81%)	0.81 (+153%)
Oils & Fat	0.07	0.10	0.03 (-57%)	0.04 (-43%)	0.03 (-57%)	0.04 (-43%)
Livestock Protein	2.90	4.06	5.85 (+102%)	8.19 (+182%)	0	0
Fish Protein	0.38	0.53	0.34 (-11%)	0.47 (+24%)	0	0
Plant Protein	0.12	0.17	0.22 (+83%)	0.30 (+150%)	1.58 (1217%)	2.21 (1742%)
Milk/dairy	0.64	0.89	0.59 (-8%)	0.83 (+30%)	0.59 (-8%)	0.84 (+31%)
Sugar	0.04	0.05	0	0	0	0
GHGs Total	**5.64[*]**	**7.89[**] (+40%)**	**8.39[***] (+49%)**	**11.74[****] (+108%)**	**3.56[***] (-37%)**	**4.99[****] (-12%)**

Table 2&3: These table represents how our dietary choice can impact the environment. More plant-based diet is recommendable from environmental perspective (Bahadur et al 9).

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