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WINNER, GLOBAL ENERGY SECURITY CATEGORY

Peak Oil and the Necessity of Transitioning to Regenerative Agriculture

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Abstract: As global energy availability begins to decline over the next several decades, energy-intensive industrial methods of food production will have to be transitioned to regenerative practices that 1) sponsor their own energy, 2) build soils and 3) produce in abundance. There are successful examples of regenerative systems that meet these three imperatives. The foundational principles of existing regenerative systems should be used in the development of new practices unique to each individual ecosystem. While borrowing principles from traditional agricultural systems, it is important that modern knowledge of biological dynamics be used in conjunction with appropriate scale technologies to enhance traditional practices and meet the three policy imperatives. The transition to regenerative agriculture is necessary to avoid being locked into a system that depletes our soils and is dependent on an energy resource in decline (fossil fuels).

The food crisis of 2008 gave a first glimpse of the problems that are emerging as global oil production peaks. As the total annual quantity of oil physically capable of being extracted from the earth begins to decline over the next several decades, agriculture may find itself dependent upon a scarce and expensive resource. In 2008, world commodity markets reached their highest levels in 30 years, food prices skyrocketed and food shortages emerged, leading to riots affecting more than 40 countries. After many years of having to deal with the negative consequences of chronically low prices, poorer nations suddenly had to deal with the opposite. With the global economic downturn starting in late 2008, both energy and food commodity prices receded from
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their high water mark. But forecasts of declining conventional oil production suggest it is only a matter of time before oil prices rise again, and a food crisis re-emerges due to higher input costs and renewed emphasis on bioenergy production to fill the drop in conventional energy sources[1].

Agriculture, like all other industries over the past century, has taken great advantage of the extraction and refining of plentiful, energy-dense, fossil fuels. Today, agriculture has evolved into a net energy user for the first time in 10,000 years—instead of being a means of converting free solar energy into metabolizable energy, it now transforms finite fossil energy into metabolizable energy. The industrial agricultural system has allowed for the cheap production of plentiful food to feed a growing population, but evidence indicates that it is ill-suited to meet the challenges of the 21st century. Over the next several decades, the practices of agriculture must reverse the fossil energy dependence and once again become a net source of energy, stop erosion and begin to regenerate soil, and meet human food needs. In other words, agriculture must transition to practices that run on solar energy, regenerate fertility and produce in abundance.

Fossil Energy Dependence

To meet the needs of a growing population, the modern U.S. food system uses 10.25 quadrillion BTU's of fossil energy inputs, or about 10% of U.S. annual fossil fuel consumption. The industrialization of agriculture has, for the first time in history, led to the situation where agriculture actually uses more energy than it creates, with 7.3 units of energy going to create and deliver one unit of metabolizable energy[2]. This energy deficit of agriculture is an historic anomaly. Up until the past 50 years, agriculture had always yielded more energy than it used[3]. Historically, by producing more energy than the farmer needed, others were freed from food production, and civilizations were built on the small positive gains in energy from agriculture. The Energy Returned on Energy Invested ratio (EROEI) of U.S. agriculture in 1920 has been estimated to be 3.1, but by the 1970s had fallen to 0.7[4]. Add the energy required to move,

[1] IEA (2008) World Energy Outlook 2008, International Energy Agency, December.

[2] Heller M, Keoleian G (2000) Life-Cycle Based Sustainability Indicators for Assessment of the U.S. Food System. Ann Arbor, MI: Center for Sustainable Systems, University of Michigan.

[3] Green, M (1978) Eating Oil: Energy Use in Food Production. Westview Press, Boulder, CO.

[4] Gifford RM (1976) An overview of fuel used for crops and national agricultural systems. Search 7:412-417.

process, package, deliver and cook food in the modern food economy, and EROEI becomes 0.14, indicating that agriculture has lost its traditional role as an energy production system and become simply another user of fossil fuels.

Historically, the foundation of civilization rested on consistent solar radiation. Now it rests on the annual extraction of finite fossil fuels. One solution is to find other energy sources, such as wind or solar, for energy-intense agriculture. Yet when comparing the EROEI ratios of the alternative fuels, the benefits of oil are apparent[5]. Today, economies are running off the large oil discoveries of the 1950s and 1960s with EROEI ratios of 50+[6]. Alternative fuels will likely have an increasing role in meeting the energy needs of the larger economy, but to believe agriculture can continue to function under the current energy balance is folly. It is imperative that agriculture return to a more balanced energy ratio over the next century.

Soil Loss

By using energy-dense inputs to produce on remaining land, industrial agriculture has been able to offset soil loss with intensification of production. But in the transition to less energy-intensive methods, continuing soil losses are not feasible. Every year 75 billion metric tons of soil erode from the earth's agricultural lands, and 30 million acres are abandoned due to over-exhaustion of the soil[7] [8]. This is equivalent to losing an area the size of Ohio every year.

Erosion is a problem that has followed cultivation for 10,000 years. Its slow effects are evident in the lands surrounding fallen civilizations such as in the Tigris/Euphrates valley, Israel, Greece or the hills of Italy. Over time, agriculture has led to the loss of one-third of global arable land, much of it within the past 40 years[9]. Green revolution methods of mechanization has sped the

[5] Bender MH (2002) Energy in Agriculture: Lessons from the Sunshine Farm Project. Proceedings of the Third Biennial International Workshop, Advances in Energy Studies: Reconsidering the Importance of Energy, Porto Venere, Italy, 24-28 September.

[6] Hall CAS, Cleveland CJ, Kaufmann R (1986) Energy and Resource Quality: The Ecology of the Economic Process. John Wiley, New York.

[7] Myers N (1993) Gaia: An Atlas of Planet Management, Garden City, NY, Anchor/Doubleday.

[8] Faeth P, Crosson P (1994) Building the case for sustainable agriculture. Environment 36(1): 16–20.

[9] Montgomery DR (2007a) DIRT: The Erosion of Civilizations.

rate of erosion in many regions and led to the abandonment of traditional practices, such as integrated crop-animal systems or polyculture plantings, that had slowed erosion and enabled some traditional systems to function for centuries[10].

Soil is a depletable resource that forms over thousands of years. It is estimated that it takes 800 years for one inch of soil to form in the American Midwest[11]. Modern agriculture is depleting soils at a rate of one to two magnitudes faster than they are formed[12]. The United States, which has much lower erosion rates than Africa and Asia, is still losing soil at a rate of four tons per acre per year[13] [14]. Once soil is eroded, it cannot be easily or quickly recreated. This use of soils can be thought of as spending the accumulated capital of millennia, not unlike the use of fossil fuels. In the past, if one culture exhausted its soils and declined, civilization could re-emerge in newly settled fertile areas. Today, with 3.7 billion acres under cultivation, there are few remaining virgin soils. If this trend of soil depletion continues, we will face an increasingly hungry world, even without the added burden of biofuels production.

Establishing Regenerative Practices

Long-term agricultural policies must be guided by three imperatives: 1) reverse fossil energy dependence and once again become a net source of energy; 2) stop erosion and begin to regenerate soil; and 3) meet human food needs. There is increasing evidence that regenerative

[10] King FH (1911) Farmers of Forty Centuries: Permanent Agriculture in China, Korea, and Japan. Published by Carrie Baker King.

[11] Pimentel D (2006) Soil Erosion: A Food and Environmental Threat Journal of Environment, Development and Sustainability, Volume 8, Number 1 / February.

[12] Montgomery, DR (2007b) *Soil erosion and agricultural sustainability*, Proceeding of the National Academy of Scientists 104: 13268-13272.

[13] USDA (2000a) Changes in Average Annual Soil Erosion by Water on Cropland and CRP Land, 1992 –1997, Natural Resources Conservation Service, USDA, Revised December.

[14] USDA (2000b) Changes in Average Annual Soil Erosion by Wind on Cropland and CRP Land, 1992 – 1997, Natural Resources Conservation Service, USDA, Revised December.

agriculture can produce more food with less energy than industrial agriculture, while increasing the health of soils[15] [16].

Regenerative agriculture[17] allows natural systems to maintain their own fertility, build soil, resist pests and diseases and be highly productive. Regenerative agriculture uses the natural dynamics of the ecosystem to construct agricultural systems that yield for human consumption. Regenerative methods regenerate the soil, the fertility, and the energy consumed in semi-closed nutrient cycles, and by capturing, harvesting and reusing resources such as sun, rain, and nutrients that fall within the farm's boundary. Other terms refer to similar principles, such as natural farming, permaculture, agro-ecology, integrated agriculture, perennial polyculture, holistic management, forest gardening, natural systems agriculture and sustainable agriculture.

Successful regenerative practices are used by small landholders capable of managing more intensive and complex systems which rely on the integration of crop-animal-human functions, use of perennial species, and the growing of multiple crops in the same field[18]. Many of these practices are based on traditional cultural land-use practices, but others are newly forged systems.

For example, one of the most promising and easily scalable methods to improve the health and productivity of large amounts of land is the use of intensive grazing—dividing a pasture into several small fields and closely managing the time livestock are allowed to graze each field[19] [20]. Evidence indicates that by finely managing when herbivores are placed in a field to graze, total

[15] Altieri M (2008) Small farms as a plantary ecological asset: Five key reasons why we should support the revitalization of small farms in the global south. Food First. USA.

[16] Pretty J (2005) The Eathscan Reader in Sustainable Agriculture. Earthscan, UK.

[17] The Rodale Institute first used this term over 30 years ago to refer to systems that continually recreate the resources that they use.

[18] Gitau T, Gitau MW, Waltner-Toews D (2009) Integrated assessment of health and sustainability of agroecosystems. Boca Raton: CRC Press/Taylor & Francis.

[19] Savory A (1998) Holistic management: a new framework for decision making. Island Press.

[20] Dagget D (2000) Beyond the rangeland conflict: toward a West that works.
University of Nevada Press.

primary productivity of the landscape can be increased dramatically[21] [22]. Grassland productivity can also be augmented through Keyline plowing, a method of widely-spaced deep chisel plowing following the contour of hillsides. This acts to shed water away from eroding valleys, directing it to water-poor ridges while increasing ground absorption[23]. The increased grassland productivity and the regenerative capabilities of the grasses take a considerable burden off of energy intensive feedlot production. Intensive grazing is a good example of a practice that is already developed and spreading on its own. It may not take much of a push for these practices to become widespread.

Another proven practice, the traditional highland Vietnamese production system (VAC) that integrates aquaculture, garden, livestock and forest agriculture in small plots, could serve as a template for other tropical regions[24]. VAC illustrates a key principle of regenerative practices—using the waste stream of one component to feed another component. Food scraps are placed in the pond to feed the fish, pond biomass growth is removed and fed to pigs, and pig manure is used to fertilize the garden and fruit trees. In this manner, regenerative systems conserve energy and maintain fertility.

VAC has other notable practices indicative of regenerative systems; it makes full use of vertical space by planting vegetables and fruiting bushes below fruit and nut trees. It uses riparian zones (small ponds) the most productive ecosystems on earth, yielding more net primary productivity per unit of area than any other ecosystem. It also stacks functions of components in the system, such as the use of the pond for waste disposal, microclimate cooling, and fish, duck, feed and fertilizer production.

[21] Brundage AL , Petersen, WE (1952) A Comparison Between Daily Rotational Grazing and Continuous Grazing. J Dairy Sci 1952 35: 623-630.

[22] Savory A (1998) Holistic management: a new framework for decision making. Island Press.

[23] Yeomans, PA (1964) Water for Every Farm: Yeomans Keyline Plan, CreateSpace, Inc.

[24] FAO (2001) Integrated agriculture-aquaculture: a primer Series title: FAO Fisheries Technical Paper - T407.

Other regenerative systems already in use include the Zai methods in the Sahel of Africa[25], the no-till rice-legume-rye system developed by Masanobu Fukuoka in Japan[26], and the edible forest system indigenous to the Kerala region of India. There are also efforts underway to develop new regenerative systems, such as the perennial polyculture system being developed at The Land Institute, which mimics the native prairie ecosystem in form and function[27].

Successful regenerative systems will look different depending on local ecosystem capabilities and constraints. By studying the foundational elements of existing systems, new practices unique to individual ecosystems can be developed fairly rapidly. Research investments should be made in locally-adapted regenerative systems. While they borrow principles from traditional agricultural systems, it is important to emphasize that new regenerative systems are not a step backwards in time. Indeed, it is critical that modern knowledge of biological dynamics be used in conjunction with appropriate scale technologies to enhance traditional practices and meet the three policy imperatives.

Extension Education and Community Investments

To begin transitioning agriculture from its current non-sustainability into practices that regenerate fertility, capture solar energy, and produce adequate amounts of food, national and international government entities must invest in:

- Creating regenerative practices appropriate for each ecosystem,
- Extension education with farmers about the value of regenerative practices, and
- Infrastructure to help farmers capture more of the value of their goods.

Although there is great potential in the widespread application of existing successful regenerative systems, they are not being adopted on a large scale. It takes time, initial resources and knowledge to transform land into regenerative systems. Without massive efforts through Extension education, widespread adoption may not result. Demonstration farms should be

[25] FAO (2008) Climate, climate change and agropastoral practices in the Sahel region. Natural Resources Management and Environment Department Publication, September.

[26] Fukuoka, M (1978) One Straw Revolution. Rodale Press.

[27] Jackson W (1980) New Roots for Agriculture, University of Nebraska Press.

established within traveling distance of every farmer to demonstrate and test locally-adapted regenerative practices. The old adage 'seeing is believing' holds very true for the world's farmers. By seeing the new practices in action, farmers will more likely adopt them, leading to further adoption by neighbors.

Agricultural infrastructure investment has typically meant more roads, ports and large storage facilities. Future infrastructure investments must be in line with future energy decline and the needs of successful agricultural systems in such an environment. Investments in electric railways and waterway transportation may be in line with declining traditional liquid fuels. Paving or graveling smaller roadways will increase access to populous markets which may otherwise be inaccessible during certain times of the year.

While large-scale national investments will be important, the most important infrastructure needs may be at the local and even farm level. At the farm level, the transition to a locally-adapted regenerative agriculture may begin with construction of ponds and swales or planting orchards. Investments in small-scale appropriate technologies, like simple bicycles, can have significant effects on poorer farmers' profitability[28]. Microprocessing technologies, such as canning equipment or oil presses, could enable farmers to process their harvest into higher value commodities closer to home.

Role of Biofuels

The three policy imperatives of agricultural transition must be the primary guide in setting biofuels policy. How can biofuels help facilitate the transition to a sustainable agricultural system that will adequately feed people, build soil and meet its own energy needs? Viewing agriculture simply as a potential source for meeting the greater economy's fuel demand will not guarantee the necessary transition, and could even exacerbate soil destruction, increase agriculture's input consumption and lead to food shortages. If appropriate, biofuels could be a vital part of long-term agricultural policy, but agriculture should not simply become a part of energy policy.

[28] Kwibuka E (2008) Coffee farmers get bikes on credit, The New Times, Rwanda, March 15, http://projectrwanda.org/news/coffee-farmers-get-bikes-on-credit. Cited March 30 2009.

How can biofuels policy help the transition of agriculture to sustainability over the next several decades? The relevant question is not the potential contribution of biofuels to reduce dependence on fossil fuels, but rather the optimal level of biofuels production to encourage the transition of agricultural to a system that enhances food security, reduces poverty and improves the earth's soils. Biofuels demand could be a catalyst creating the right conditions for a transition to a truly regenerative agriculture, particularly if that demand moderately increases all commodity net returns. If crafted within a larger agricultural policy matrix, biofuels policy can be part of the solution.

As energy becomes scarce in the coming decades, agriculture must transition to practices that run on solar energy, regenerate soil fertility and produce in abundance. These three policy imperatives should be the long-term guideposts in setting all policies that affect agriculture. The importance of meeting this transition should not be undervalued—if we fail, the future of our complex society could be in jeopardy.

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