Moving Beyond the Orthodoxies in ‘Sustainable Agriculture’

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Moving Beyond the Orthodoxies in ‘Sustainable Agriculture’

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「持続可能な農業」をめぐるOrthodoxiesを超えて

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The term ‘sustainable agriculture’ has much currency but multiple and even contradictory meanings. It is often used to indicate small- and mid-scale, agribiodiverse and farmer-centered agricultural production. At the same time, in the context of global population growth and agriculture’s aggregate impact on the biosphere, the term ‘sustainable agriculture’ is mobilized to justify further intensification of industrial agricultural systems. In this view, current and future demand for food is writ large, and it is asserted that only high-yield conventional agriculture can meet it. The key research question is how to mitigate industrial agriculture’s negative ecological impact while retaining its productivity.

‘Demand’ is therefore critical to assessments of sustainability. Yet future estimations of demand rest on incomplete and often dubious figures of present agricultural production and greatly varying assessments of food availability, consumption, and waste. As a consequence, the widely forecast ‘doubling of demand’ is tautologous: it presumes present patterns of consumption which are themselves the result of industrial-scale agricultural production. An agenda for agricultural development predicated on the need to meet a ‘doubling’ of demand therefore diminishes the real and imaginary territories in which alternative food futures lie.

Both small- and large-scale visions of sustainable agriculture can be called ‘orthodoxies’ in that the adherents of each vision assume their preferred scale of analysis is the essential one, while dismissing the insight and analysis offered by the other. This paper should demonstrate that both per-

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spectives offer important insights into the problem of agricultural sustainability, but that *neither* can fulfill its potential so long as it remains an orthodoxy. The research traditions surrounding smaller-scale and larger-scale agriculture can be brought into fruitful dialogue.

「持続可能な農業」という言葉が世間に流布しているが，その意味は多様で矛盾すらはらんでいる。この言葉は通常，中小規模，多品種栽培，農民主体の農業生産を表すために使用されてきた。しかし一方で，世界規模の人口増加や農業の生物圏への全体的な影響という文脈では，産業的な農業システム，すなわち大規模，単一作物栽培，主として企業主体の農業，の増強を正当化するために用いられている。そこでは，今日および今後の食料需要が強調され，需要を満たすには現行の高収量農業のみが妥当であるとされる。この場合，重要な研究課題は，産業的な農業が，その生産性を維持しながら，どうやって負の生態学的影響を緩和するかということになる。

このように，持続性の評価において，食糧「需要」はきわめて重要な要素である。しかしながらその食料需要の将来予測は，不完全で疑わしい点も多い農業生産に関する統計や，見解が大きく相違する食料の調達，消費，廃棄に関する複数の推定に基づいている。そのため，地球全体の食料の「需要倍増」という予測は同語反復になっている。なぜならば，需要予測が，それ自体，産業的な農業生産システムの結果である現在の消費パターンを前提としているからである。このような同語反復的な需要予測をすることは，将来のありうるべき農業を考えるための，現状認識と想像力を誤らせることになりかねない。

小規模であれ大規模であれ，自分たちの規模に合致した分析のみを絶対視し，もう片方の洞察と分析を受け入れない「持続可能な農業」を，ここでは“orthodoxies”と呼んでおく。そのうえで本論では，どちらの視点も農業の持続性に関して重要な洞察を提供しうるのだが，それぞれがorthdoxyに留まる限り，その可能性を実現できないことを示す。これまでの両者の伝統的な研究は，お互いが対話することにより，実り多いものになるのである。

1 The problem of sustainable agriculture

The concept of 'sustainable agriculture' has much currency but multiple and even contradictory meanings. This paper introduces, examines, and suggests reconciliation between two principal, and divergent, conceptualizations of agricultural sustainability. As food has become a global commodity, and food scares have taken on multi-national dimensions, many people intuitively associate the concept of 'sustainable agriculture' with a variety of endeavors that shorten the geographical and conceptual distance between food production and consumption. Farms that are small in scale, agrobiodiverse, sometimes organic, and not substantially dependent on off-farm sources of key inputs are often assumed to be 'sustainable'.

In quite a different vein, the term 'sustainable agriculture' is also mobilized to justify further intensification of industrial agricultural systems. In this view, described at length below, agricultural sustainability is defined relative to global population growth, global demand for food, and agriculture's aggregate impact on the biosphere. In this global vision, agricultural sustainability is defined in terms of yield per unit of ecological impact, a metric by which smaller-scale endeavors are judged insufficient. As a consequence, the key research question is how to mitigate conventional agriculture's negative ecological impact while retaining its great productivity.

Though they come into play in different contexts and have different ranges of influence, both visions can be called 'orthodoxies' in that the adherents of each vision assume their preferred scale of analysis is the essential one, while dismissing the insight and analysis offered by the other. This paper should demonstrate that both perspectives offer important insights into the problem of agricultural sustainability, but that neither can fulfill its potential so long as it remains an orthodoxy: the research traditions surrounding smaller-scale and larger-scale agriculture can have fruitful dialogue.

The assumptions of both research traditions are coming under increasing scrutiny. In the field of 'agrifood studies' (Niles and Roff 2008) recent work has taken unreflexive localism and blind-faith in the ecological integrity of organic foods to task (Brown and Getz 2008; Guthman 2004). This paper emphasizes the global-centric vision of sustainable agriculture, and identifies the category of 'demand' as a critical—but flawed—element in the argument in favor of intensification of industrial agrisystems. It finds that future estimations of demand rest on incomplete and often dubious figures of present agricultural production and greatly varying assessments of food availability, consumption, and waste. In accepting orthodox forecasts of a 'doubling' of demand, and insisting that only intensification of conventional industrial agricultural production can meet this demand, adherents of the global vision draw attention away from the social and ecological dynamics of agricultural intensification and dismiss smaller-scale producers and non-conventional agriculture out of hand. A re-evaluation of the concept of ‘demand’ should focus attention where it is most needed: on the social, policy, economic, and ecological dynamics that can maximize food production in a manner appropriate to local and regional biophysical qualities, agrarian traditions, and food cultures.

The body of this paper is comprised of four main parts. Following this introduction, Part 2 describes the local and global perspectives of agricultural sustainability in greater depth. Part 3 outlines the biophysical evidence underlying the case for intensification of industrial agrisystems. Taking the biophysical evidence at face value, Part 4 then turns to examination of the empirical and conceptual grounds underlying the critical concept of ‘demand’. Part 5 suggests that there may be an emerging convergence in the key questions driving agroecological research, and so an opportunity to shift this research so that it simultaneously enables best farmer practices and yield productivity.

2　Visions of sustainability

2.1　local perspectives

In colloquial terms, sustainable agriculture is commonly identified with a host of ‘alternative’ agricultural endeavors and products, including organic produce, organic farms, community supported agriculture (CSA) endeavors, and farmers’ markets (Niles and Roff 2008a; 2008b). In its contemporary commercial guise, organic agriculture can be traced back to 1970s countercultural environmentalism, though as both an alternative set of techniques and ideology it has more distant antecedents (Beeman and Pritchard 2001). Until recently, organic produce, where it could be found—invariably in ‘health food’ stores, along with brown rice, bulk molasses, and sugarless candy—was for ascetics only. Popular (fast) and fine (French) food, in contrast, represented largess and easy living. Even as organic production has ‘gone industrial’ and organic foods have crossed over to the shelves of both high-end and mass retailers (e.g. Guthman 2004; Pollan 2006), contemporary organic production inherits, and many organic producers actively promote, an environmentalist ethos in which ‘organic’ is a synonym for ‘sustainable’.

In the United States food and agriculture have also become touchstones in burgeoning urban concerns of ‘food justice’ (Lappé and Terry 2006), challenging the common association of organic food with upper-middle class white people (e.g. Slocum 2006). In interstitial urban settings, food justice projects promote local production and consumption of nutritious food—in contrast to the sugar- and salt-laden fare commonly available at corner stores—in place of much certified organic produce, with its common price premium and long supply-chains. Countless community gardens and a handful of public school-based endeavors and innovative community based organizations such as (in the San Francisco Bay Area alone) the Frugal Foodies, People's Grocery, Mobile Market, and Edible Schoolyard, attempt to kindle interest in quality, healthy food among inner-city populations, and especially young people. In these cases, sustainable eating, with its implications for community health, slightly displaces sustainable agriculture. The 'food justice movement' puts food quality into the context of community development, public health, and community beautification. With its immediacy and liveliness, its focus on urban parks and gardens, common kitchens and good home cooking, food justice provides a welcome break from the more fractious and pavement-bound organizational tactics and objectives of much 'environmental justice' activism to date. Of course, food justice activists also describe the local tactics as part of a broader endeavor towards 'sustainability' (Lappe and Terry 2006).

Another perhaps lesser-known group of advocates of sustainable agriculture in the United States espouses what is sometimes called 'New Agrarianism'.[1)] The vision for new agrarianism entails a return to, or creation and support of, land-based rural societies in place of the austere cultural landscapes created by conventional, industrialized 'Big Agriculture' across the principal agricultural areas of the U.S. Early texts of New Agrarianism described the intertwined economic, ecological, and ethical concerns accompanying the rise of 'Big Ag', usually as experienced directly by family farmers (Berry 1977; Jackson 1985). Much of this literature gives first-hand description of what Jackson (1985) called 'the failure of success', the farm-level economic devastation and environmental degradation accompanying the immense increase in U.S. agricultural productivity in the post-War period. As implied in the moniker, 'New Agrarian', there is also attention to what can be done to alter the course of U.S. agricultural change (Wirzba 2003), at both macro- and micro-scales.

Much New Agrarianism is associated with Mid-Western Land Grant universities. In recent years many of these have formed institutes of sustainable agriculture. The emphasis is usually on mid-size,[2)] family-run agricultural endeavors. Perhaps a best-elaborated proposal to restructure U.S. agricultural production is in process under the title 'Agriculture of the Middle'. The program outlines a vision for middle-scale sustainable agriculture, and the policies that could support such change.[3)] Complementing this proposal are studies such as that by Bell (2004), a rural sociologist, describing the micro- and community-relations that accompany individual farmers' decisions to turn away from conventional corn and soy rotations and intensive animal facilities. In their place, some Mid-Western farmers are establishing more complex, intimate, and remunerative agro-systems, such as pasture animal systems, and longer, more crop-diverse cereal rotations. The example and proposed New Agrarian agro-systems sometimes resuscitate earlier practices and at other times evolve new techniques, such as low- or no-tilling, manure management, or flame cultivation. The features of these agrisystems are worked-up—and communicated—farmer-to-farmer and farm-by-farm[4)] through recurrent field-level experimentation. The agrisystems that develop are considered sustainable because they are at once economically feasible—they sustain human communities—and amenable to local biophysical conditions.

There is some long-standing awkwardness in relations between such different groups espousing 'sustainable agriculture',[5] but there are important shared understandings between the groups as well. In general the favored agricultural endeavor is small- to mid-scale (farmer- and community-centered), as localized as possible in terms of source of inputs and destination of produce, sometimes organic, agrobiodiverse, labor intensive in comparison to conventional agrisystems, and tailored to local environmental conditions. These are characteristics that are mostly commonly discussed in relation to farm, community, or landscape perspective or scales (e.g. Pretty 2003). At base, the most common conceptual and practical model for such 'alternative' agricultural endeavors is an ecosystem that runs on sunlight and recycles materials, but there is also a significant ethical aspect to sustainability, both in terms of individual and community stewardship of land (Berry 1977), and general access to quality and affordable food (Gliessman 1997; Francis 1990). For all concerned, agricultural sustainability involves human community as much as ecological process.

Before describing a quite different assessment of the character of agricultural sustainability, it is useful to briefly summarize several empirical and conceptual elisions common to the approaches and literatures cited above. First, 'sustainable agriculture' is often used as a catch-all concept; especially in the popular press, there is a common assumption that any local agricultural project, if it is non-polluting, is 'sustainable'. Second, while the meteoric increase in consumer interest in organic and other non-conventional production[6] has inspired a proliferation of new studies, perhaps this researcher interest is out of proportion with the significance of smaller-scale production within conventional agrifood systems. Buttel (2001: 176), for example, cautioned against researcher fascination with "the local as local, and for its symbolic, but not economic (in terms of number of workers, farmers, or value of aggregate production) significance within the larger agricultural community".[7] Finally, much research has emphasized relatively small-scale case studies of agricultural sustainability and assumed that what is sustainable in a local context is equally so in a larger one. Although this paper attempts to show that the predicted of trends population growth and urbanization can be allowed to eclipse other, equally critical aspects of 'sustainability', this is hardly to argue that such trends should be ignored.

2.2　Global perspectives

A wholly distinct vision of agricultural sustainability is developed in discussions of current and expected world food demand and production, one that makes little or no mention of organic production, agrarian society, or the relatively small-scale, low-input, biodiverse agriculture described above.[8] In the 'global vision', 'agricultural sustainability' is described in terms of the challenge to world agriculture posed by the need to meet an anticipated doubling of global demand for food by mid-century (Conway 1997; Tilman et al. 2002). The question of total global food supply, global demand, and the global ecological impact of both has been taken up in a number of influential fora and by a number of authors (Conway 1997; Dyson 1999; 2001; Tilman et al. 2001; Tilman 1999; Green et al. 2005; Fedoroff and Cohen 1999; Cassman 1999; Ruttan 1999).

This specifically global concern has shifted the terms of the discussion of agricultural futures. Earlier population/resources discussion tended to emphasize technological and resource (soil, water) limits that would inhibit food production. In the case of agriculture, productivity was typically framed in terms of X quantity of available land (or water, nitrogen, or another factor), which if producing at Y yield/hectare, would or would not be able to meet Z demand. In present discussions, in contrast, agricultural productivity is evaluated primarily in terms of its impact, as presently known, on the nutrient and hydrologic cycles that sustain the biosphere. The preeminent research question is: how much food can be produced at what impact to individual cycles and ultimately to the entire biosphere? The challenge for science, as in the title of one publication, is "Meeting cereal demand while protecting natural resources and improving environmental quality" (Cassman et al. 2003).

In the global perspective, there is no single fundamental threat to the cumulative productivity of conventional agricultural systems—no imminent collapse due to soil erosion, declining fertility of soils, water scarcity, or other factor. None of the authors considered here advocate revolutionary change to the dominant agricultural systems; none promotes the near-term need for paradigm-changing technological innovation such as the use of biotechnology.[9)] As a consequence, what is advocated is not a simple 'greening' of industrial agriculture, but instead economic and ecological intensification: increases in yield per hectare under cultivation and in relation to the environmental impact of this production, what has been called a 'doubly green revolution' (Conway 1997). Thus, agricultural sustainability is framed as a question of yield per unit of ecological impact. By this metric only industrial agriculture can qualify as sustainable agriculture.

3 The case for intensification: demand, yield, and ecological impact

The case for intensification of industrial agriculture rests on the interaction of three key factors: (1) demand for food, (2) agricultural yield, and (3) the ecological impact of this yield. Each factor will be considered in turn.

3.1 Demand

As supplying food is the primary function of agriculture, demand is a principal concept in the history of agricultural theory (e.g. Boserup 1965; Geertz 1963; Malthus 1926 [1798]; Netting 1993). Though demand can be examined in relation to cultural, ecological, and political-economic factors, it is also commonly considered in simple terms as the total amount of calories, nutrients, and protein necessary to sustain the metabolic functions of an individual or population given certain patterns of consumption. According to the Food and Agriculture Organization (FAO), average world food consumption in 2003 was 2809 calories/capita/day (FAO 2006). Approximately 75% of these calories were gained from vegetable matter, 12% from vegetable-based oils and fats, the remainder from animal products (FAOSTAT 2007a). In calories and in kind actual consumption figures vary widely from place to place; in aggregate, however, world cereal production in 2004 was estimated at 2.2 billion tons (FAOSTAT 2007b). FAO (2003: 4) estimates that the additional 2.3 billion people expected by 2030 will require another one billion tons of production per year, an increase in production almost equal to that since 1960. Other estimations regularly cite estimations of a likely doubling of demand for food by mid-century (Tilman et al. 2002). The satisfaction of this demand is taken as a base condition of agricultural sustainability.

Two processes increase global demand for food. First, global population is increasing, though its rate of increase is declining. After peaking in the late 1960s at 2.04% per year, the rate of global population increase fell to below 1.35% per year by the end of the 1990s. The rate of increase is expected to continue to fall to .5% per year by mid century, when global population will number, and perhaps eventually stabilize at, approximately 9.3 billion (FAO 2003: 4). Dyson (1999: 5932) cites this population growth as the “chief cause” of increased demand for food to 2025.

The second source of anticipated demand stems from increasing wealth (Grigg 1999). Historically, as household income increases, people who previously had difficulty satisfying their daily need for calories consume the food that gives the most calories for the least cost, typically cereals and root crops. With further increments in income, people often shift to a preferred staple (e.g. wheat or rice in place of rye or millet). In either case, such people eat ‘close to the sun:’ that is, most efficiently in terms of conversion of solar radiation to human foodstuffs. Once a basic caloric threshold is surpassed, however, people generally trade up, typically eating more fresh vegetables, fruit, plant oils, sugar, alcohol, and animal products such as milk, dairy products, eggs, fish, and finally meat, foods that require more energy per consumable calorie (Smil 2001: 8–9). The dietary shift from largely vegetarian to mixed meat diets appears to hold across cultures (Grigg 1999).

As a whole society’s wealth increases, consumption patterns change again, this time in relation to increasing urbanization, industrialization and commercialization of agrifood systems, changes in household labor dynamics, as well as changing public definitions of health and diet (Goodman and Redclift 1991; Popkin 1993). People in wealthier, more urban societies eat more of everything, especially more meat, but also consume large amounts of processed foods and they often eat away from home (Grigg 1995: 64–65; Goody 1982). In the age of globalization, food commodity chains stretch between continents, and sourcing of raw materials, transport, processing, and retail have multinational dimensions (Weiss 2007). Thus, over time, the satisfaction of demand for food requires ever-more energy, both as people eat 'further from the sun', and in the number of transaction points between harvest and consumption in mass societies.

In the global view, at the aggregate level, not only will the two to three billion people expected by 2050 need to eat every day, but most of these people will be urban dwellers; they will eat more per person, and, because of expected increases in consumption of animal products, they will eat less efficiently. Although in aggregate there is already a surplus of available food, extrapolating from FAO (2003) figures one finds a 52.6% increase in agricultural production will be necessary to meet a 27.7% increase in population by 2030. In this estimation, agricultural production must become more efficient because consumption will become less so.[10)]

3.2 Yield

Forecast demand leads quickly to the question of present and potential agricultural yield. Usually at issue is the yield of the three primary cereals, maize, rice, and wheat. Wheat is the most important crop in terms of production tonnage, rice in terms of direct human consumption, and maize in terms of trade (Dyson 1996: 27). The production and consumption of these three cereals is often used as proxy for all food production and consumption. Together the three provide approximately half of all calories directly consumed by humankind (Dyson 1996: 27). In total, when cereals fed to livestock and fish and eventually consumed by humans as meat are considered, they provide two thirds of the total bulk and energy in human diets (Tilman et al. 2002: 674; Cassman 1999). As a group rice, wheat, maize are described as "the foundation of global food security" (Cassman 1999: 5952).

According to Cassman (1999: 5952), the principal cultivation systems of the three plants include "(i) irrigated annual double- and triple-crop continuous rice systems in the tropical and subtropical lowlands of Asia, which account for about 25% of global rice production, (ii) irrigated annual rice-wheat double-crop system, which is the primary cereal production system in northern India, Pakistan, Nepal, and southern China, (iii) temperate maize-based, rain-fed cropping systems of the North American plains, which contribute more than 40% of global maize supply, and (iv) the favorable rain-fed wheat systems of northwest and central Europe, which account for more than 20% of global wheat supply". Each of these systems operates in its current state due to a series of largely twentieth century innovations that coalesced in the 'Green Revolution'.

Implemented through the coordination of international agricultural stations beginning in the 1960s, though with deeper historical roots (Brookfield 2002: 219–220), the Green Revolution entailed profound changes to the infrastructural, mechanical, biochemical, and biological aspects of agricultural production. Modern techniques of irrigation increased agricultural lands under irrigation by 97% between 1961 and 1999 (Green et al. 2005), and these lands now produce about 40% of total food supply (Smil 2001: 41).[11)] Working in tandem with irrigation, relatively cheap water-soluble nitrogenous fertilizers provided the key nutrient necessary for plant growth, and enabled significant increases in both cropping density (number of plants of a species grown per hectare) and cropping intensity (the number of annual harvests) (Evans 1989). Other significant developments, such as the invention of pesticides and herbicides and increasing on-farm mechanization, enabled monocrop agricultural production on a scale never before possible.

3.2.1 Harvest Index

At base, however, the effectiveness of irrigation, fertilization, mechanization, and pest and weed control in increasing yields was dependent on deliberate crossing of two or more genetic strains of a plant species. The principal goal of modern plant breeding efforts has been to increase the proportion of useful to nonuseful biomass produced by specific plants, a ratio also known as harvest index (HI). Traditional varieties of wheat, for example, yielded 20–30% of edible matter per plant (HI of .2-.3). Late twentieth century hybrid wheat varieties gave an HI of .5 (Smil 2001: 28), most of the savings gained through crossing prolific seed producers with shorter, stronger stalked ‘dwarf’ varieties (Evans 1989: 92).

Even under ideal conditions, however, modern crops are not any more photosynthetically efficient than their wild ancestors, and neither domestication nor modern breeding has increased their rate of growth (Smil 2001: 28).[12)] In some cases, even with some varieties of wheat, total biomass has increased only 5% from early varieties (Evans 1989: 92). As long as crops depend on the sun for energy, grow in soil and are subject to weather, they can put only so much energy into producing seed without compromising the structural integrity of root and stalk systems or leaf surface available for photosynthesis. At present, the breeding of principal cereal crops appears to have achieved a close balance between plant structure, reproduction, and yield. Though there is some possibility of raising maximum HI in the near future (Evans 1989), only slight gains can be expected for the existing major crops, and with great investment (Cassman 1999: 5954–5955; Ruttan 1999: 5962; Smil 2001: 29).[13)]

At the field level, a similar situation exists. The productivity of modern plant varieties is dependent on ideal field conditions; in sub-optimal conditions modern crop yields may not equal those of traditional varieties (Cleveland, Soleri, and Smith 1994). Yield potential, or the crop yield in a particular place under best available environmental conditions (where nutrients and water are non-limiting and pests and diseases are controlled), is well known for major crops in the principal intensive management systems. In aggregate, yields are near or at 80% of their potential in important cropping areas in Korea, Japan, China, and Mexico. Yields did not rise continuously in India, the Philippines, and Indonesia, though they were below 80% of potential (Cassman et al. 2003: 321–328); a 'yield gap' (between actual and potential yield) still exists in these systems. Once yields approach the maximum potential, however, further increases are difficult to achieve. According to Cassman et al. (2003: 321):

> As average farm yields approach the yield potential threshold, it becomes more difficult for farmers to sustain yield increases because further gains require the elimination of small imperfections in the integrated management of soil, crops, water, nutrients, and pests. In general, such rigorous fine-tuning is not economically viable on a production scale such that yield stagnation typically occurs when average farm yields reach about 80% of the yield potential ceiling.

In most developing world countries, future yield increases are likely to be related to reductions in stressing factors that inhibit productivity, not to increasing yield potential. Access to water in many countries remains a primary limitation on yield increases, indicating the need for agronomic practices that emphasize soil management in order to increase water infiltration and reduce runoff. For Cassman (1999: 5953, 5958), even the "daunting challenge" of changing micro-management of "hundreds of millions of small rice and wheat fields" across the developing world, though crucial to local food security, will likely have limited impact on the global food-supply balance. Yield increases in such contexts will be "small, incremental" (Cassman 1999: 5955). Instead, Cassman finds the "greatest opportunities for sustained yield increases from further intensification are found in irrigated and favorable rain-fed systems where present average farm yields are less than 70% of yield potential" (1999: 5954),[14)] and where the scale of operation is great enough to justify the high cost of precise management equipment.

3.3 Ecological impact

Just as plant physiology limits yield potential from within, agriculture as a whole is under pressure from without. At least since the publication of Silent Spring in 1962 (Carson 1994 [1962]), agricultural fields have been widely acknowledged as point sources of pollution. Now there are better understandings of the dynamics of local degradation, how local actions contribute to secondary source pollution, such as ground and surface water pollution, and how collectively these are of regional and global ecological significance (Fedoroff and Cohen 1999; Matson et al. 1998; Smil 2001; Tilman et al. 2001). This section reviews some of the key ecological impacts of agriculture, and their relevance to sustained agricultural production.

At present, "[t]he global agricultural enterprise is passing a threshold" (Tilman 1999: 5998); a 'business as usual' forecast (in which input : yield and land : yield relationships remain the same) of the next doubling of food production would entail “a worldwide tripling of the annual rates of N and P fertilization, a doubling of the extent of irrigation, and an 18% increase in the amount of land farmed” (Tilman 1999: 5996). Since this specifically global description of conventional agriculture’s ecological impact is key to arguments for further intensification of industrial systems, a brief review of this impact is useful.

Agriculture generates the three leading greenhouse gases, Carbon Dioxide (CO_2), Methane (CH_4), and Nitrous Oxide (N_2O). Carbon stored in plant matter and soil is released to the atmosphere through conversion of natural ecosystems to crop- and grazing-land, and by repeat plowing and harvesting of land. Methane, the single most potent greenhouse gas, is responsible for about 18% of the artificial greenhouse effect, and agriculture is responsible for approximately half of global methane emissions (Steinfeld et al. 2006). Methane is released to the atmosphere from rice fields, which have increased in area by 7% per year in the last 30 years, and from enteric fermentation within cattle, whose numbers have increased by 5% per year in the same period (Smil 2001: 93; Barry and Chorley 2003: 18). Irrigation accounts for 80% of global consumption of freshwater (Cassman et al. 2003),[15] but about half of the water used in irrigated sprinkler systems vaporizes, surplus water vapor in the atmosphere also contributing to the greenhouse effect (Barry and Chorley 2003).

The continuous or near-continuous cultivation of single crops in conventional agriculture is dependent on synthetic nitrogenous fertilizers, but these are often over- or mis-applied, with direct effect on soil fertility and surrounding environments. Intensification increases pressure on soil fertility, since increases in yield or in harvest index extract more soil nutrients and reduce the amount of plant phytomass available for recycling. Maintaining soil fertility in intensive management regimes is a serious concern (Matson et al. 1998), especially as yields per unit of added synthetic fertilizer are declining, and it is estimated that only 35–50% of applied fertilizer is taken up by crops (Tilman et al. 2002: 673; Smil 2001: 112).

In total, agriculture has doubled phosphorus mobilization, and almost doubled total annual nitrogen inputs in global terrestrial ecosystems (Tilman et al. 2002: 673). Phosphorus run-off leads to eutrophication in freshwater lakes and streams, and costly pollution of drinking water (Merrington et al. 2002).[16] Excess nitrogen contributes to salinization and acidifying of soils, nitrification of fresh- and salt-water sources, and acid deposition (‘acid rain’). Artificial nitrogen (NO) also inhibits the formation of ozone (O_3) in the stratosphere, while the nitrogen species NOx catalyzes ozone formation in the troposphere (Barry and Chorley 2003), damaging human health and reducing agricultural productivity by as much as 10% (Smil 2001: 88–89). Though under the Montreal Protocol its use is now largely prohibited, methyl bromide, a broad-spectrum pesticide, is responsible for 10% of the decrease in the stratospheric ozone layer (Smil 2001: 88). Industrial agriculture thus decreases ozone in the stratosphere, where it blocks incoming short-wave radiation, and increases O_3 in the troposphere, where as photochemical smog it retains outgoing long-wave radiation. Both result in increased surface temperatures (Barry and Chorley 2003: 51).

Agriculture also has special relevance to biodiversity. Agriculture has entailed continuous land conversion and biological simplification of ecosystems since its invention 11,000 to 6,000 years ago, with lasting effect on non-target flora and fauna. Population growth, agricultural intensification, habitat modification, and decrease in agrobiodiversity can form a positive feedback cycle. Indeed, agro-ecosystems have become highly specialized over time, with one, two, or three species favored to the exclusion of all others. In a global lens, approximately 37% of the terrestrial surface is used for crops and pasture, a number far surpassing the built environment (FAO 2003). In the United States, for example, 46% of total area is categorized as cropland, pasture, or range lands (Vesterby and Krupa 2001), while impermeable surfaces (roads, parking lots, buildings, etc.) amount to about 112,610km^2 (Elvidge et al. 2004), or about 1.4% of the continental U.S area.

In the age of industrial agriculture, pesticides and herbicides directly control field-level biodiversity, reducing the need for crop-rotations, companion planting, and the presence of non-target species, whether beneficial or benign. Raven and McNeely (1998) and Pimm and Raven (2000) summarize and contextualize the current 'extinction spasm', which in some places is indicated by extinction rates 12,000–30,000 times the background extinction rate (the historical rate of die-off given dynamic biophysical conditions). Impressed on more than a third of the Earth's surface, and encroaching throughout the species-rich tropics, agriculture is clearly implicated in the current pace of extinction. Biodiversity conservation is also used as a justification for further agricultural intensification, as described in the following section.

3.4 The solution: ecological efficiency

For the litany of environmental problems, supporters of the vision of industrial intensification hold that agriculture is at a crossroads, but not at imminent crisis. Despite its impact on the biosphere and differences of opinion regarding the exact fix required, in the global view, only industrial-scale global agriculture, and the science and policy supporting it, enabled food production to stay apace of twentieth century population growth and increasing demand for food. In this sense, for its cumulative ecological impact, ever-increasing intensity of agricultural production is credited with reducing the need for conversion of much land to agriculture in the post-War period of explosive population growth. In short, in this view, industrial agriculture has actually preserved environments and beneficial ecological services. Similarly, yield increases on best agricultural lands will reduce the need for conversion of more land to agriculture in the future. Dyson (2001: 448) summarizes the assessment:

> If population growth is going to be the main element behind the expansion of world food

> demand over this time horizon, then *yield* growth will be the key to the future expansion of the world's food supply. Indeed, yield growth will be absolutely crucial—because the only alternative way of raising food output is by increasing the *area* of harvested land. Yet, particularly in the very populous regions of Asia, there is very little new land that can be brought into cultivation. And in much of the rest of the world...it is only through the achievement of higher yields that land will be spared for nature.

Green et al. (2005) provides a most recent and apposite summary of the argument supporting industrial agriculture's aggregate ecological efficiency. Evaluating the demand and yield dynamics of recent years and those—especially the doubling of demand—expected in the near future, the authors ask "how this enormously increased demand can be met at the least cost to the other species with which we share our planet" (Green et al. 2005: 550).

Using bird populations, for which they state there is good data in international contexts, as a proxy for biodiversity, the authors compare 'land sparing' agriculture (that which increases yield/hectare on existing agricultural lands) and conservation biologist-favored 'wildlife friendly' agriculture (that which allows more wild species to persist on farmland through the creation of buffer zones and the like). In their calculations, the key equation is that between yield and bird population densities. The authors find that even though high yields are associated with lower species and diversity counts at the field-level, high-yield agriculture may allow more species to persist at the landscape, regional, or national scales. Although they mean to point their results toward redesign of agri-environmental policy in the European Union, the authors cite several developing world case studies in which agricultural intensification reduced the need for conversion of intact habitat to agricultural lands. The paper concludes that there is likely a choice "between having a greater area of low-yielding wildlife-friendly farmland and less intact habitat or having a smaller area of high-yielding, less wildlife-friendly farmland and more area available for wild nature elsewhere" (Green et al. 2005: 553).

In the global view, then, it is generally accepted that only industrial-scale agriculture is capable of meeting current and expected global demand for food without affecting the biophysical base in a manner that jeopardizes yield dependability. For its proponents, both the demand-led scenario and the predominantly ecological assessments supporting their vision are increasingly obvious, non-negotiable, and urgent. The associated industrial, institutional, and social configurations that would define 'sustainable agriculture' must follow. By extension, smallholders (and in fact the societies to which they belong) who have long been described as economically inefficient (cf. Mayer 2002), are now determined to be agro-ecologically inefficient: their lower-yielding lands would be best left to provide ecological services as 'intact habitat'.

4 Is there no alternative agriculture?

Is there no sensible alternative to intensification of industrial agricultural production along the lines described above? At issue here is not the question of ecological impact, but the widely cited and apparently incontrovertible demand scenario inspiring the stated need for intensification of industrial systems. Three principal weaknesses in the demand-driven argument can be identified; in total they provide support for the argument in favor of a more heterogeneous agriculture. First, both production and consumption figures are subject to substantial inaccuracy and should be viewed with some skepticism. Second, in large-scale assessments (e.g. Dyson 1996), production figures are used to determine consumption, and consumption is used to determine future demand. As a result there is little to distinguish the three terms descriptively or analytically, leading to an intellectual inflexibility about their relations in contemporary agrifood systems. Finally, the global vision for sustainable agriculture is generally consistent with Boserup-influenced theory of agricultural development in which demand drives yield. The demand → yield conceptualization of agricultural change may not describe contemporary agrifood systems, or have much relevance to the dynamics of contemporary hunger.

4.1 The empirics in ‘demand’

The question of how much food humankind does or will need should follow from an understanding of how much is now produced and consumed, but these elemental figures are difficult to establish. The most commonly cited figures of national-level food production and supply are those of the United Nations’ Food and Agriculture Organization (FAO). The FAO publishes Food Balance Sheets (FBS) for most countries annually; these contain the basic data regarding national food supply. FBS also rely on the FAOSTAT database, which gives national level agricultural production and import/export data. FAO datasets are widely cited to establish the current state of hunger and malnourishment (as with the World Food Summit in1996 and the 2000 U.N Millennium Summit), and, when combined with U.N. population statistics, to make estimations of future food supply and demand (e.g. Alexandratos 1999; FAO 1995; 2003). Since they often provide the empirical ground on which issues of national food policy are determined, these data thus have clear relevance to the well being of people around the world.

Within the FBS, a most important value is total food supply. Total food supply is established by adding production of foodstuffs and food imports together and adjusting for changes in food stocks. From this figure are deducted food exported, used for feed, seed, or in manufacturing, and lost in storage or transportation. The final amount of food available is then divided by population, and per capita calorie availability is used as a proxy for per capita intake (FAO 2001).

Though FAO acknowledges “many gaps” in data (FAO 2006), of data that are provided on FBS there is often no indication of its provenance, reliability, or the likelihood or direction of its error, any of which could have considerable impact on estimates of undernourishment. The problems of data accuracy in matters of food production and consumption are many, and include developing and developed world countries. Jacobs and Sumner (2002), in their FAO sponsored review, and Svedberg (1999) noted insufficiencies and obscurity in the base data used to determine food supply. Both reports arrive at similar conclusions, that food supply is “a residual with unknown size or direction in its error created from variables that are subject to considerable error or contain other residuals” (Jacobs and Sumner 2002: np). According to Smil (2001: 193), for example, FAO figures differ from daily means derived from consumption surveys in wealthy nations by no less than 20–25%, and from those in the U.S. by 40–45%, while FAO figures on per capita red meat consumption in the U.S. differ by 22 kg/year with U.S.D.A. figures, and by 8 kg with those of France.

Several problems internal to the FBS should undermine confidence in their unqualified use in policymaking. For the purposes of this paper, inadequacies of base food production and consumption data can be summarized into several questions.

4.1.1　How much land is under cultivation?

Many countries have no agricultural institutions or take no regular statistics on agricultural productivity, and as a consequence crop data are inferred from secondary data points, such as population. Even in countries with access to quality measurement equipment, agricultural data are often estimated based on secondary sources. Area of cultivation is also difficult to estimate in areas of chronic conflict or other serious disruption. As a result, Smil (2001: 182–184) estimates errors from 5–25% of actual area figures.

4.1.2　How much food is produced?

Total food production/year is another basic value that can be difficult to establish. FAO data on this question are uncertain in two distinct ways. First, since many countries lack a coordinated measurement system, total food commodity production is often estimated based on estimated lands under cultivation. Even if these figures were to be accurate, it does not account for pre-harvest losses (field losses due to pests, weeds, and pathogens), estimates of which run from 10–15% to even 50% of total production in a given year (but see below) (Yudelman, Ratta, and Nygaard 1998). Second, the production, collection, and consumption of non-marketed food are captured in very few national-level assessments, despite its importance in different contexts. Smil (2001) cites cases in which hunted meat provided approximately 20% of all animal protein consumed, and gathered foods, either wild or domesticated, may provide important nutrients on a seasonal basis and in periods of scarcity.[17] Where subsistence production is included in FBS, such as for Sub-Saharan African areas where swidden agriculture is practiced, estimations of its extent may be low by 25% (Svedberg 1999: 2090).

More significant in urbanizing areas, garden production is absent in FBS, though gardens may provide otherwise limited vitamins and micronutrients, especially among people eating low-energy (high starch) diets. Garden production is often not just incidental to other livelihood strategies; at the household scale gardens have been documented to supply up to 40% of a household's caloric requirements and 20% of its income (Netting 1982). Finally, food production figures are extremely difficult to verify in rapidly expanding urban areas, off-grid con-urban agglomerations, or cities with large informal sectors. Imagine estimating the number of chickens raised in Mexico City.[18]

4.1.3 How much food is available for consumption?

Data on harvest and post-harvest losses of cereals (losses incurred during handling, threshing, drying, storage, and milling) are difficult to establish and verify (Tyler 1982). Estimates of such loss vary widely, and sometimes losses in a particular instance are mistakenly ascribed to an entire nation. Sober estimates of post-harvest cereals losses often surpass 10% of the total harvest; in some years losses may be as high as 40%. Losses of tubers, fruits, and vegetables can often be higher than 25%, those of fish, even higher (Smil 2001: 182–183, 186; FAO 1989).

4.1.4 How much food is actually consumed?

Smil (2001) estimates only one third of FAO consumption figures are supplied directly by respective nations (and may still be of dubious accuracy), while the rest are estimated, culled from existing data, and processed at the Rome headquarters. Of given FBS figures, these indicate average per capita intake/year and have little predictable relationship to actual food intakes at a particular time and place. Even if food consumption surveys—which generally establish the most reliable accounts of consumption—are used, caloric and nutritional measurements must be taken at the micro-scale, in real time, and be updated repeatedly for accuracy. FBS do not address variability in total food supply or access to calories among regions of a country, in different seasons, or among members of a household (FAO 2001). Since the kind and quality of food consumed varies greatly within populations (the urban/rural divide is increasingly apparent), through time, and within households, such averages can obscure as much as they reveal, especially regarding an individual's nutritional, rather than simply caloric, status.[19] The question of food waste adds another level of uncertainty to consumption estimates, as quantity of waste is extremely difficult to document. For estimates of waste, FAO often relies on expert opinion alone (FAO 2006).

In sum, even at household scales of analysis, it is difficult to know not only how much food is produced, but how much is consumed, and by whom. As a result, on a purely empirical level, 'demand' for food is difficult to determine in all but the coarsest terms—terms that are of little relevance to food security in a particular time and place.

4.2　The concept of 'demand'

In global assessments of future food security there is descriptive overlap in the terms 'production', 'consumption', and the projection and character of 'demand'. As in the following passage, demand is usually defined as current consumption plus that attributable to additional population expected at a particular date.[20)]

> [I]n projecting future levels of cereal 'demand' we are not concerned with the difficult and contentious issue of projecting nutritional or food requirements. Rather, future demand will be defined with reference to current levels of [cereal] consumption—irrespective of how inadequate, or excessive, these levels may be (Dyson 1996: 101).

This conflation of contemporary consumption and future demand leads to an intellectual inflexibility about the relationship between current production and present and future demand. In particular it follows from—and leads to—the assumption that current levels of production are determined primarily by human demand for food. Yet the relationship between agricultural production and food consumption can be highly tenuous. As a result the research agenda driven by a demand → yield conceptualization of agricultural change may not describe change within contemporary agro-food systems, or have much relevance to principal causes of hunger and malnutrition.

Industrial production of maize serves as a good example of the skewed relationships between production and consumption. In the USA, 93.6 million acres (almost 3.79 million hectares) was planted with corn in the 2007–2008 market year (NCGA 2008),[21)] accounting for almost one quarter of total of US harvested crop area. Only an extremely small part of the more than 13 billion bushels (330 million metric tones) produced (ERS 2008)—estimated to amount to about 40% of global maize production—was consumed directly by humans. Approximately 70% of the total US harvest was used as animal feed or for ethanol production, and over 10% was used to produce high fructose corn sweetener and other sweeteners, corn starch, alcohol, cereals, and other processed foods. Almost 19% of the harvest was exported (NGCA 2008), often for use as feed in intensive animal facilities, though in some cases part of this quantity was consumed directly.[22)] In short, despite the immense productive energies invested in US production, corn has relatively little relevance to food security. If a good portion, almost 46% of total production, becomes animal feed, this is a question of market allocation, not human need. Indeed the goal of associations such as the National Corn Growers' Association is not to address global food security, but to promote the economic interests of particular maize producers.

Complex contemporary agro-food systems are distinguished by extremely long commodity chains, complex interaction with nutritional and agricultural policies, multiple transformations/processing stages of staple foodstuffs, high degree of vertical integration in transportation, storage, processing, and retail, and an extremely active and influential advertising sector. In such systems it is difficult to clearly ascribe current levels of food production, demand, or consumption to economic, ecological, caloric, or nutritional parameters. For example, Heffernan (1999; 2000) describes how grain-seed corporate 'clusters' now control large agro-commodity flows stretching from the laboratory and patent office to the supermarket shelf. Numerous transactions and conversions occur 'in-house', at undisclosed prices, along the length of the production chain. Industry concentration is usually defended through theoretical arguments of economic efficiency (comparative advantage delivers the cheapest food the consumer), but if prices are invisible, economic estimations of supply and demand are impossible.

The labyrinthine character and sheer size of agrifood systems ought to raise the question of the extent to which yield may presently determine, or at least directly affect, demand. The question is especially relevant to demand for meat—demand that is enabled by industrialized corn and soy production—since most of agriculture's forecast negative environmental impact is attributable to intensive animal production (Tilman et al. 2003). At the global level (according to the FAO), animals consume one third of all cereals, about 670 million tons of grain a year (Speedy 2003). With the significant exception of China, meat production is highly concentrated in surplus cereals producing countries and regions,[23)] so that it appears that contemporary trends of meat production and consumption have less to do with historical change in consumption patterns than they do with a industrialized agricultural systems that consistently provide cheap cereals to intensive animal facilities.

Instead of entering into closer examination of production-consumption linkages, those taking up the question of global agricultural sustainability accept demand trajectories as given and set about seeking technical solutions for the crop systems . Yet if demand for food, and especially for luxury items like beef, is inevitably linked to a number of other social/cultural, ecological, and political-economic factors, its satisfaction does not occur according to some natural law, but instead is bound up in a wider political, economic, and technical context. In questions of future global food supply, this wider context in which demand takes place—the context of relatively cheap fossil fuel energy, cheap cereals, and cheap meats—is rarely acknowledged.

4.3 Effective demand

An important but seldom mentioned caveat in discussions of the 'doubling of demand' is that as used 'demand' does not refer to a fundamental (caloric or nutritional) human need for food, but to effective demand, or the “the ability of countries [or people] to pay for cereals at the prevailing international prices” (Dyson 1996: 477). In an agro-food industry increasingly characterized by vertical and horizontal concentration (Hendrickson and Heffernan 2007), most profit is gained by adding value through food manufacturing and processing. As a result, more of a given staple does not necessarily translate into more food availability or cheaper food prices. There is evidence that increases in food (especially cereals) production can lead to greater food insecurity among the rural poor, for several reasons. Increases in food imports can be harmful—not helpful—to the rural poor, whose abilities to provide for themselves are undermined by simultaneous price decreases in staple crops and usurpation of local markets in which to sell their produce (Desmarais 2007). In rural Mexico, Kelly (2001) documented increases in food insecurity since formal agricultural policy liberalization in 1994: the market price of maize fell by half, while the cost of tortillas doubled in the same period (Ray, de la Torre Ugarte, and Miller 2003). Even when increases in food production are achieved through national production, as in India, middle-class demand for meat may prove more powerful than that of the poor for basic foodstuffs. According to Dasgupta (1998: 27), “the annual rate of growth of cereal consumption in the poorest countries during 1966–1980 was 2.9%, whereas that of feed was 3.8%”.

In sum, demand figures are of dubious quality and the demand → yield conceptualization of agricultural change may not describe contemporary agro-food systems, or have much relevance to the dynamics of contemporary hunger. In combination, the overbearing emphasis on demand dynamics draws attention away from the dynamics of agricultural intensification, and that of smaller-scale producers and non-conventional agriculture within intensification. There is a kind of intellectual path-dependency set by mutually reinforcing precepts and conclusions, all of which function to the exclusion of small- or medium-holder agriculture.

5　Converging research agendas?

The overriding objective in most farm-level agricultural change is to increase yield, and thereby improve quality of life. It remains so today, in all kinds of agriculture. Yet the fixation on yield as arbiter of economic success and agricultural technique has obscured integrated assessment of intensively managed smaller-scale agriculture. Aside from eliding measurements of ‘total output’ that would account for multiple foodstuffs produced by a biodiverse agriculture over the course of a season or year, the emphasis on yield narrows down to a single point a whole field of human activity and ecological process (Pretty et al. 2002; Rosset 1999). Nevertheless, the category of yield endures as a key distinguishing dynamic between large- and small-scale agriculture. Several recent papers demonstrate that, as they attract sustained research attention, yield gaps between conventional and non-conventional agriculture are declining.

Pimental et al. (2005) found that in a given year organic production systems produced lower cereal yields than conventional systems, by about 15% over a 22 year period.[24)] In periods of drought, however, organic systems yielded 28–34% more than conventional maize production with increased groundwater recharge and reduced runoff. Also, total energy requirements for non-conventional maize production were 28–32% lower than for comparison conventional production (Pimental et al. 2005: 575).

Mäder et al. (2002) had similar findings in a 21-year comparison of organic and conventional cereal systems. Organic yields were 20% lower than conventional yields over 37-year crop rotation periods, but losses of N, P, and K were 34–51% lower than in conventional systems. Also, energy consumption per unit land area in organic systems was 36–53% lower than that required in conventional systems. Organic systems have also been found to support more active and efficient denitrifier communities and to reduce N losses (Kramer et al. 2006). Organically farmed orchard soils had higher total N, higher organic matter content, and greater presence of enzymes indicative of microbial N and C cycling potential (Kramer et al. 2006: 4523).

Some techniques and principles of agro-ecology have become increasingly relevant to large-scale agriculture because they offer immediate ecological benefits. The techniques of 'landscape-scale management', such as the planting or maintenance of buffer strips around fields, streams, rivers, and lakeshores, as well as field-level practices such as intercropping, no-till cultivation, and the application of insights of Integrated Pest Management (IPM), have worked their ways into the mainstream (e.g. Tilman et al. 2002: 674). Such practices provide multiple widely recognized agro-ecological benefits, aiding in crop pollination, creating habitats for beneficial insects, increasing the number of insect predators, and reducing the quantity of weeds, all of which are significant elements in attempts to reduce pre-harvest loses.

Agriculture is generative, not simply extractive, and agroecological analysis emphasizes the dynamism of overlapping soil, flora, fauna systems of a particular place (Gliessman 1997). Agriculture, while entailing a 'semi-domestication' (Hecht 1995) of natural ecosystems, also represents one of humankind's most successful efforts at augmenting ecological integrity and creating biodiversity. Agroecologists have long claimed that sound agricultural management can produce high and quality yields while also enhancing local ecologies (Fukuoka 1978). The possibility that appropriate agroecological practices can enhance local ecological integrity is supported by the finds of Brookfield, Parsons, and Brookfield (2003). In their assessment of on-going agricultural projects in Africa, Asia-Pacific, and Latin America in the 'People, Land Management, and Ecosystem Conservation' (PLEC) project, they find that "there is strong indication that biodiversity enhancement is possible (if not always achieved by the majority) by particular types of [land] management".

Conventional industrial and smaller-scale agricultures are easily seen as incompatible: the science, policies, practices, and even eating habits that suit one appear to inhibit the other. In fact, there is notable convergence of research interests of agroecologists and scientists who seek intensification of conventional systems. For decades, agroecological research has emphasized “specific interactions in biological systems, and how they can be used to reduce or fine-tune fertilizer and chemical inputs”, as well as nutrient cycles, “efficiency of nutrient use, genetic resistance to insect and pathogen pests, weed and insect ecology and population dynamics, crop rotation effects, and biological interactions among plants, insects, pathogens, and microorganisms” (Francis 1990: 103). These same dynamics were identified as important areas of research by the National Academy of Sciences (Fedoroff and Cohen 1999).

If intensification of agricultural systems is a goal shared within both large- and small-scale perspectives, it is worth paying close attention to a range of potential causal factors. Boserup (1965) noted that the critical element in agricultural intensification is often knowledge. The question is, whose knowledge? A narrowing range of field-level skill and new labor arrangements characterizes the history of post-WWII agricultural development, as synthetic inputs were taken as effective substitutions for farmers with real agro-ecological knowledge (e.g. Desmarais 2007: 43–45). If intensification of industrial agricultural systems along the lines described above requires skilled field-level action, the supporters of industrial intensification are in the paradoxical position of supporting the regime of agricultural production that has proven most antagonistic to agroecological farmer knowledge (Bell 2004, for example).

Improving knowledge does not simply entail undertaking more research. The U.S. National Research Council’s 1989 report (National Research Council 1989) noted the context in which much agricultural research takes place. According to Thompson (1995: 25):

> The NRC reports question the academic or scientific integrity of the agricultural research system, arguing that the methods for identifying research priorities and funding agricultural science continue to be too much influenced by parochial and non-scientific interests. Primary among these interests are agribusiness firms.

Thompson noted that: “public funds [are] spent in a manner that effectively subsidizes research costs for chemical companies, or that benefits directly corporations by increasing the market for their herbicides” (1995: 38–40). The emphasis of much agricultural research and development on new technologies that will either increase productivity or fine-tune application of agricultural inputs amounts to more of the same, and represents the proclivity for technological solutions to agroecological questions.

Netting remarked on Westerners’ tendency to seek agricultural intensification through technological means, yet concluded that "[t]echnological invention and scientific discovery are not the crucial causal factors in the course of agricultural intensification" (Netting 1989: 57). A close reading of Boserup (1967) reveals that intensification (or de-intensification) can be considered as a fundamentally cultural phenomenon: it occurs as farmers assess their needs in relation to the kind and quantity of land and techniques available to them. Further, intensification is a landscape-scale phenomenon—and usually not one myopically focused on a single crop—that occurs as rural peoples shift their efforts within a set of activities, or from one set of activities to another. In agrarian societies, and especially in land-scarce, population-dense, areas—precisely those purportedly most in need of conventional agriculture—Netting's advises farmers to 'skill up, don't scale up'. The utility of the research agendas described above will depend on the availability of the science at the field level; its assimilation into actual farming systems will likely depend on farmer-scientist collaboration of the kind described in Brookfield (2003) and Brookfield et al. (2003).

Farmers in economic crisis have few opportunities to invest in best practices. When left without access to good land or reduced to tenancy or contract labor, they have little incentive to manage the lands to which they still have access for long-term productivity (FMRA 2005). Farmer organizations of North and South suggest the institutional structures most conducive to increasing the productivity and ecological performance of their local agricultures (Desmarais 2007). Such proposals have direct relevance to the dynamics of hunger and rural development, the discourses of food security, and the goal of agricultural sustainability, as well as to the places of rural peoples in rural landscapes and our collective imaginaries of the meaning of 'rural' (Niles, in press).

Statements, such as that by Tilman et al. (2003: 671) that "industrial agriculture now feeds six billion people" reinforce the claimed indelible association between conventional industrialized agriculture and sustainable agricultural production. With over one billion of the global population partially or wholly occupied as food producers (Windfuhr and Jonsen 2005), the figure is off by 18%, at least. Such statements mask the current and potential productivity of people with agroecological knowledge, who instead of being seen as potential participants in a broad-based, mutli-scalar attempt to redefine sustainable agriculture, appear only as potential recipients of cheap food policies and the future dependents of industrialized agriculture.

6 Conclusion

The world's population is increasing within a biosphere whose dynamic interactions and finite proportions are better understood than ever before. The classic population/food resources dilemma is now framed not only in terms of the spatially or technologically bounded availability of a particular resource, but in terms of the chemical and biological processes that create the biosphere. Advances in integrated environmental science and the prospect of a stabilizing global population allow the opportunity to estimate aggregate human impact in terms of *global* ecology and energetics (e.g. Vitousek 1997). In such terms it is possible to estimate how much direct and indirect drag humankind puts on biogeochemical cycles, and speculate about its significance.

The great strength of such a perspective is that it supersedes sectoral analysis of phenomena like agriculture, whose material flows and social significance so easily slip out of strictly disciplinary boxes. Yet in making the case for intensification of industrial systems, and in separating agriculture from nature, agriculture is re-sectoralized (e.g. Waggoner 1996). The ecological impulse behind the concept of sustainable agriculture—of linking human needs with their ecological impact—is translated into an attempt to make agriculture as ecologically benign as possible, separate from a 'nature' that is best left undisturbed.

The estimations of future consumption so significant to the argument for intensification of industrial agriculture are predicated on, and largely indistinguishable from, the most statistically visible patterns of contemporary food production. Both current and future consumption are naturalized as demand (Cassman et al. 2003), a growing and unquestionable force. Assertions that only intensification of industrial agrifood systems can address demand are therefore tautologous: the intensification is necessary to meet future demand, and future demand can only be met by intensification; yet demand is defined by measures based on the present system of supply, marketing, and consumption. The present production patterns, food inefficiencies, and dominant market context are simply applied to the future. The global vision thus erodes the real and imaginary territories in which non-conventional agrifood systems do, and can, exist.

Dasgupta (1989) remarked that concerns for the environmental resource base of human life are often posed in global and futuristic terms. This tendency can have two effects that inhibit, rather than resolve, population-resource questions. First, an excessively global perspective tends to lead to all-or-nothing positions and prophecies of doom or boom.[25)] Second, a preoccupation with pragmatic solutions to future problems draws attention away from the character of these same problems in the present. Instead,

> the interface that connects the problems of population growth, poverty[,] environmental degradation, food insecurity, and civic disconnection should ideally be studied with reference to myriad communitarian, household, and individual decisions … if we are to reach a global, futuristic vision of the human dilemma, we need to adopt a local, contemporary lens (Dasgupta 1989: 19–20).

Recent study of rural sustainability emphasizes the social practice of sustainability. 'Sustainable agriculture' in this sense is not just an alternative set of agri-

Image 1: Industrial soy production in Mato Grosso, Brazil. Photo courtesy of www.fernandoweberich.com.

Image 2: An example of a mid-scale agricultural landscape. Kocourov, Czech Republic. Photo by Petr Kovar, courtesy of www.sxc.hu.

cultural techniques, or alternative set of social relations. It is a diverse set of social practices linked to agriculture and food (Bell 2004: 16–18). It involves reforming food commodity flows and reassessing consumption habits. With continued urbanization and population growth, industrialized agriculture is likely to persist in the near future. In many regions of the world, localizing the geographical and conceptual space in which food production and consumption occurs will be beneficial. Doing so will provide the well-documented benefits of smaller-scale agriculture, and perhaps lead human societies towards a clearer and more responsible position within the seamless life processes of the world.

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Notes

1) A convenient shorthand for decades of quite disparate research and advocacy. Wendell Berry and Wes Jackson, to name only two individuals, are often claimed as early influences.
2) In the context of the Mid-West corn and soy agriculture, ‘mid-size’ is around 300 acres.
3) See www.agofthemiddle.org for justification of the mission and progress to date, case studies, and supporting literature.
4) National and international farmer exchange programs are one of the features distinguishing contemporary agrarian activism from previous farmer activism, and giving it an internationalist politics. See Bell (2004) for an intimate portrait of farmer exchange in the U.S., and Desmarais (2003), Edelman (2003), and Bove (2001) on international farmer exchange and political organization.
5) For example, there can be tension between mid-Western New Agrarianists and organic-production oriented ‘environmentalists’ (Bell 2004; Telleen 2003).
6) In the United States, for example, the size of the organic market has increased approximately 20% per year since 1990 (Dimitri and Greene 2002) and the total area of land in organic production doubled between 1992–1997, and doubled again for many crops between 1997–2003 (Economic Research Service USDA 2005). Yet in total only 0.4% of all cropland and 0.1% of all pasture is certified as organic (Economic Research Service USDA 2005), and sales of organic produce in 2003 (totaling $10.4 billion) amounted to only 1.8% of total retail sales of food (Oberholtzer, Dimitri, and Greene 2005).
7) See also Evans, Morris and Winter (2002) and Heffernan (1999).
8) The contrast in visions of agricultural sustainability is not new (Dahlberg 1991).
9) For example, Dyson (1999a: 155) cites the historically incremental nature of agricultural change, and cites Ruttan’s statement that “Advances in conventional technology will remain the primary source of growth in crop and animal production over the next quarter century”. In a separate article, Ruttan (1999) also emphasizes the changing orientation of agricultural research toward private sector interest in neutraceuticals and pharmaceuticals, and notes the “excessively broad patent rights being granted in the field of biotechnology [which] may become a serious institutional constraint on the transfer of plant protection and animal health biotechnology products to farmers in developing countries.”
10) See also Popkin (1993).
11) Seventy-five percent of rainfall irrigated agriculture remains in the developing world (Evans 1989: 90).
12) Modern breeding has not manipulated photosynthesis as a biochemical process, but by increasing proportional leaf size (L.A.I., or leaf area index), it has increased overall plant growth. I thank Peter Matthews for pointing me to the distinction.

13) Evans (1989: 94) writes that there is "still limited scope for further increases in the harvest index… when agronomic advances [such as better weed and pest control, and closer control of nutrient and water supply] permit their use". For the longer term, "much will depend on whether selection for higher rates of photosynthesis that translate into faster growth proves feasible. So far this has not happened…". Cassman (1999: 5955) concurs.
14) In this category fall Indonesia, North America, Pakistan, northern India, Nepal, China, central Europe, Argentina, and Brazil
15) Smil (2001: 42) estimates agriculture claims about two-thirds of total use, or about 5–7% of global freshwater runoff.
16) In the U.K. Pretty et al. (2000) estimate clean-up costs of agricultural pollution are equal to one third of total agricultural value/year.
17) Manioc gathered from fallow fields, steamed and sometimes sweetened with garden-harvested honey, was a frequent filling treat while I lived in eastern Yucatan Fall-Winter 1996. Also, fallowed lands were regularly visited for a range of building materials and other utilitarian goods.
18) A friend who lives within 20 minutes of UNAM in Mexico City tells of a small cattle dairy in the neighborhood.
19) Dasgupta (1998) noted how it is possible to have adequate access to calories yet remain deficient in micronutrients necessary for healthy growth.
20) Slightly different figures, higher by about 10%, account for economic growth-based dietary transition (Dyson 1999).
21) 73% of the total acreage was seeded with biotech hybrid seeds (NCGA 2008).
22) Japan was the leading importer of US corn, receiving about one quarter of all US exports (NCGA 2008).
23) Half of global meat production is concentrated in China (28%), the U.S. (15.28%), and Brazil (7.37%) (FAO 2004). Of meat exports, 80% come from Brazil (28% of world total, a meteoric rise since the late 1980s), the U.S. (21%), the E. U. (14%), Canada (9%), and Australia (8%) (USDA 2005).
24) From the farm perspective, the lower productivity was offset by the price premiums of organic products.
25) E.g. www.earth-policy.org. (Accessed 11 February 2009).

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