

Article

# Sustaining without Changing: The Metabolic Rift of Certified Organic Farming

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**Abstract:** Many proponents of organic farming claim that it is a sustainable alternative to conventional agriculture due to its reliance on natural agro-inputs, such as manure based fertilizers and organic pesticides. However, in this analysis we argue that although particular organic farming practices clearly benefit ecosystems and human consumers, the social context in which some organic farms develop, limit the potential environmental benefits of organic agriculture. Specifically, we argue that certified organic farming's increased reliance on agro-inputs, such as organic fertilizers and pesticides, reduces its ability to decrease global water pollution. We review recent research that demonstrates the environmental consequences of specific organic practices, as well as literature showing that global organic farming is increasing its reliance on agro-inputs, and contend that organic farming has its own metabolic rift with natural water systems similar to conventional agriculture. We use a fixed-effects panel regression model to explore how recent rises in certified organic farmland correlate to water pollution (measured as biochemical oxygen demand). Our findings indicate that increases in the proportion of organic farmland over time increases water pollution. We conclude that this may be a result of organic farms increasing their reliance on non-farm agro-inputs, such as fertilizers.

**Keywords:** organic farming; metabolic rift; conventionalization thesis

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## 1. Introduction

Organic farming is often put forth as a sustainable alternative to conventional agriculture, claiming to rely on ecologically sustainable practices that are more in line with earth's natural ecology [1,2]. This has helped to increase the popularity of organic goods around the world, as sales on organic farms have risen five-fold over the past decade and a half [3]. The recent success of organic farming is also partially due to the rise in organic certification, a process whereby external entities, usually government organizations, create a unified definition of organic farming to regulate the practices used by farmers and help consumers identify organic goods [2,4,5]. While there are clear merits to having a cohesive definition of organic farming, some have argued that certification is being used to integrate the organic industry into the agribusiness industry by regulating standards in a way that increases the economic viability of organic agriculture. Specifically, some researchers have suggested that organic certification leads to a "conventionalization" of the organic market, by watering down standards and increasing the use of inputs produced off farm, such as non-synthetic fertilizers and pesticides, to reduce the risk of direct farm investments [6–8]. If tilling methods and fertilizer management practices are being refashioned on organic farms to serve economic interests over ecological interests, then the ability of nations to reduce specific environmental hazards caused during agricultural production by shifting toward organic practices may be weakened. In particular, it has been noted that even though organic goods have clear environmental benefits in terms of biodiversity protection and human health [9–11], they can have similar, and in some instances higher levels of nitrate leaching as their

conventional counterparts if certain practices (e.g., seasonal crop rotations and manure management) are not implemented properly [10–14].

To this end, we draw on an environmental sociological theory known as metabolic rift [15], to demonstrate how the conventionalization of the organic market may limit the ability of organic farming to address some of the ecological cost of agricultural production. Specifically, we contend that the conventionalization of organic farming reduces its ability to mend the metabolic rift between agriculture and natural water systems. We empirically test our assumption using a fixed-effects panel regression model to examine whether increases in the percentage of organic farmland cross-nationally from 2003–2007 reduced biochemical oxygen demand (BOD) in water, while controlling for population, percent urban population, and gross domestic product GDP (social components known to drive various environmental impacts including BOD).

## 2. Organic Farming and the Conventionalization Thesis

The rise of certified organic farming has been met with many criticism by social scientists. The most prevalent criticisms have been brought forth by scholars developing the conventionalization thesis, which hypothesizes that as certified organic farming grows, it begins to mimic conventional agricultural practices. The term conventionalization was first proposed by Buck *et al.* [6] to describe the changes occurring within organic agriculture in California. The authors utilized the concept to convey the transition of organic farming from an idealistically driven counter cultural movement, to a slight variant of conventional agriculture. Buck *et al.* [6] and Guthman [7], found that organic farming was increasingly becoming industrialized, relying on non-farm inputs, such as machinery, fertilizers, feed, agrochemicals, and resource substitutions, to stimulate production. This resulted in a bifurcation of the organic market, creating of two organic systems—one more in line with the original ideals of the movement that emphasized local small scale farming, direct consumer sales, and prohibited the use of non-farm inputs, and another economically driven market that helped to integrate organic agriculture into the agribusiness industry.

More recently, the conventionalization thesis has been expanded to focus on global organic practices. For example, Best [16] found that newer organic farms in Germany show signs of conventionalization, noting that newer organic farmers tended to use slightly larger farms and had more specialized operations. Additionally the author found that recent adopters did not share the same “pro-environmental” values as earlier farmers. Flaten *et al.* [17] similarly found that newer organic dairy farmers in Norway used more concentrates and had higher milk production yields, highlighting that while all organic farmers shared favorable views toward the environment, older farmers had much stronger views and placed more emphasis on soil fertility, fertilizers, and pollution. Läßle and Van Rensburg [18] in Ireland, also found that late adopters of organic farming expressed lower environmental values and were much more profit driven than early or medium adopters. In the Netherlands DeWit and Verhoog [19] found that conventional agro-food commodity chains were increasing and the use of non-farm inputs in organic farming. Specifically, the authors noted that conventional fertilizers were consistently being used in organic pig and poultry production.

These studies, although specific to particular locations, demonstrate a potential shift in organic farming practices globally. Furthermore, if these practices are becoming more prevalent globally, they may alter the ability of organic farms to reduce water pollution. Below we discuss the ecological implications of organic farming practices *versus* conventional farming specifically in regards to water pollution, to demonstrate the environmental impacts of organic agricultural practices.

## 3. Organic Agriculture and Water Pollution

Agriculture is one of the largest contributors to global water pollution. It increases the amount of organic contaminants found in natural water systems and produces chemical imbalances through the extensive use of pesticides and fertilizers [14]. Pesticide runoff is known to increase bioconcentration, which is the accumulation of chemicals on or in organisms, and biomagnification, where chemicals

become more concentrated as they move up the food chain in ecosystems and may induce biodiversity loss [20]. While a lot of organic farms do use pesticides [2,4,5], organic pesticides have not been linked to water pollution, and there are currently no studies finding a clear relationship between organic pesticides and water pollution. Thus at this time, there is no reason to believe use of organic pesticides increases water pollution.

Organic fertilizers that contain nitrogen and phosphate on the other hand, can leach into soil and create algal blooms in surface water, causing overall oxygen levels in water to decline, which also can result in biodiversity loss in natural water systems [21]. This process often occurs when water drains through soil, taking with it the nitrates contained in the soil. Organic fertilizers, such as animal manures that contain nitrogen, have specifically been linked to nitrate leaching when nitrate is added to soil while drainage is occurring, when more nitrate is supplied than needed for a crop to grow, and when there is a lack of synchrony between nitrogen supply and crop uptake [9]. Shepard *et al.* [9] also notes that “if soils are left bare during fall or crops are poorly developed, there will not be an effective rooting system to utilise the soil N that is mineralised after harvest and this will be at risk of leaching over the winter” (p. 37).

Some studies that observe levels of nitrate leaching between organic and conventional farms argue that organic farms have lower levels of nitrate leaching due to overall lower inputs of nitrogen [9,22–24], however, the bulk of these studies relies on data from specific organic and conventional farms and were conducted prior to what recent research that is seen as the conventionalization period of organic practices. Furthermore, studies conducted during this same period noted that in some instances organic agriculture had similar or higher leaching rates than conventional farms. For instance, Kristensen *et al.* [25] showed that the average nitrate content in soils between conventional and organic farms that used manure-based fertilizers in fall was slightly higher in organic farms, and far higher in organic farms *versus* conventional farms that did not use manure-based-fertilizers. Condron *et al.* [26] found in simulations that nitrate losses were similar between conventional and organic farms during rotations in New Zealand. Stopes *et al.* [27], also found that during rotations nitrate leaching was similar for conventional and organic farms that used under 200 kilograms per hectare of fertilizer, but were greater for organic farms receiving more than 200 kilograms per hectare of fertilizer. More recent studies have also concluded that nitrate leaching is similar and in some instances slightly higher on organic farms [12,13]. For example, Tuomisto *et al.* [14] in a systematic study of research observing the environmental impacts between organic and conventional farms, concluded that nitrate leaching per unit of area was 31% lower on organic farms, but 49% higher per unit of product on organic farms.

Comprehensively, these studies demonstrate the degree to which water pollution derived from nitrate leaching is induced by conventional and organic farming. Furthermore, they reveal that in order for organic farms to have lower levels of nitrate leaching than conventional farms, they must use specific management practices, which include seasonally conscious crop rotations as well as careful and limited inputs of nitrate-based fertilizers. While organic farming is often promoted as an agricultural method more in line with Earth’s natural ecology, the requisites for this are diverse and complex, and may be limited based on the social context in which organic farms are developed. For instance, the conventionalization thesis has revealed that over time organic farmers have become less concerned with the environment, less strict about farming practices, and more economically motivated [6,17,18]. These trends produce an organic agricultural system that is less cognizant of the practices necessary to reduce bio oxygen demand in water, due to decreasing concern about and application of methods necessary to combat nitrate leaching. Additionally, the processes of conventionalization work to increase the size of organic farms, and the concentration of inputs used on organic farms. Based on criticisms of proponents of the conventionalization thesis and the analyses of natural scientists regarding the practices necessary to reduce nitrate leaching, it is reasonable to believe that organic farming may not function as a counter-force to all forms of water pollution derived from agricultural production, but in fact perpetuate specific types of water contamination. Below we further develop this argument using the environmental sociological theory metabolic rift.

#### 4. Organic Farming's Metabolic Rift

Metabolic rift was developed by John Bellamy Foster [15] to refer to Marx's expression of the "irreparable rift in the interdependent process of social metabolism" [28] (p. 949). The term is based on Marx's writings regarding metabolism and the development of soil chemistry and the use of fertilizer in agricultural production. Foster argues that Marx acknowledged the growing contradictions between capitalism and nature in his observation of Liebig's work and the British agricultural revolution. There, Marx proposes that capitalism is breaking the natural laws of sustainability in its use of fertilizers to restore nutrients to the soil that were lost during large scale agricultural production. Marx also accuses "large landed property" of "reducing the agricultural population to an ever decreasing minimum" and as a result, the concentration of populations in cities, leads to "a squandering of the vitality of the soil" (because all soil nutrients end up in city sewers rather than the land) [28] (p. 949). He further contends that "The way that the cultivation of particular crops depends on fluctuations in market prices and the constant change in cultivation with these prices—the entire spirit of capitalist production, which is oriented towards the most immediate monetary profits—stands in contradiction to agriculture, which has to concern itself with the whole gamut of permanent conditions of life required by the chain of successive generations" [28] (p. 754). In essence, as Foster [15] notes, Marx argues that the application of market values to agricultural production contradicts the ecological forces that sustain farm systems. This included the ever increasing size and scale of farms as well as enhanced reliance on non-farm inputs, such as nitrates, phosphates, and potassium derived from manure and guano that are added to soil to maintain and increase fertility.

While Marx's concern with the application of fertilizers was on soil sustainability rather than water pollution produced from nitrate leaching, the notion of metabolic rift has also been further developed to explore capitalism's inherent contradiction with sustainability. Clark and York [29] apply the term rifts and shifts to the process "whereby metabolic rifts are continually created and addressed (typically only after reaching crisis proportions) by shifting the type of rift generated" (p. 17). They argue that "To the myopic observer, capitalism may appear at any one moment to be addressing some environmental problems, since it does on occasion mitigate a crisis. However, a more far-sighted observer will recognize that new crises spring up where old ones are supposedly cut down" [29] (p. 17).

We expand on this argument, and contend that the socioeconomic conditions influencing organic agriculture mirror those influencing conventional agriculture, as a result, the environmental degradation developed by organic agriculture is similar to the environmental degradation of conventional agriculture. For instance, just as the metabolic rift observed by Marx was a result of the town-country divide, which was addressed by increasing the amount of non-farm inputs used in agriculture, we argue that conventional organic farming is a refashioning of this metabolic rift, relying on natural rather than synthetic inputs. This is to say that the production of industrial organic farming (the conventionalized cousin of the original organic movement) is simply a change in the technology used in agriculture's previous metabolic rift, shifting to the use of natural inputs (ironically the inputs observed in Marx's original analysis) instead of synthetic inputs. However, agriculture's metabolic rift was never about the inputs, but the structural processes necessary to maintain society's destructive relationship with nature. Thus in order to address industrial agriculture's rift with nature, nations must address the economic as well as technological context of agriculture. Before discussing how we model and test these assumptions, we briefly review previous research using metabolic rift theory and discuss how our research builds on this tradition.

Metabolic rift theory has been used by social scientists to contextualize the environmentally hazardous outcomes of various forms of social organization. For example, Mancus [30] examined the metabolic rift in global agriculture markets. He argues that structure of industrial agriculture, which is defined by the overuse and dependence of inorganic nitrogen fertilizer, has breached the social metabolism between society and the nitrogen cycle, creating massive environmental pollution in natural water ways and soil erosion. In a similar vein, Gunderson [31] applies metabolic rift theory to analyze large-scale livestock production, showing how the environmental impacts of

industrial livestock production increase greenhouse gas emissions, and pollute natural water systems. Clausen and Clark [32] apply metabolic rift theory to marine systems, demonstrating how intensified production of aquaculture systems and overfishing practices pollute natural water systems and reduce aquatic biodiversity.

Others have expanded metabolic rift theory by focusing on the historical development of science and technology. For instance, Clark and York [33] focus on the historical development of science and technology to explain the metabolic rift between industrial civilization and the carbon cycle. Moore [34] provides a historical examination of environmental history using metabolic rift theory to explain the rise of global capitalism and the development of the world system.

In a fashion similar to these works, we apply metabolic rift theory to further explore the rift between modern social organizations and the natural environment. We expand the theory of metabolic rift by examining how it offers critical insights into mechanisms of sustainability, specifically, organic agriculture. Additionally, we adopt the conceptual framework of rifts and shifts to explain how organic farming is a result of shifting industrial agriculture's rift from synthetic agrochemicals to organic practices. We argue that the process of conventionalization, specifically, the vertical and horizontal integration of the organic market, mirrors the structure of the conventional agricultural industry by increasing organic farms' reliance on non-farm inputs. In turn, these inputs help to increase the economic viability of the organic market by increasing the financial gains of organic pesticide and fertilizer manufacturers [6]. This leads conventionalized organic farms to produce the same metabolic rift that Marx identified in his observations of the British agricultural revolution.

## 5. Hypotheses

Based on the theory discussed above we hypothesize that as the proportion of organic farming increases over time, it becomes more conventionalized, resulting in an expansion in industrial agriculture's rift to water ecosystems. To this end we ask if there is a positive correlation between organic farming and water pollution. The contrasting hypotheses we test are:

H1: Increases in the proportion of certified organic farmland is correlated positively with biochemical oxygen demand.

H2: Increases in the proportion of certified organic farmland is correlated negatively with biochemical oxygen demand.

We attribute hypothesis 1 to the conventionalization thesis and the theory of rifts and shifts, where the vast majority of certified organic farmland is increasing biochemical oxygen demand in water due to weak management practices and a shift in the technological methods used in farming. Hypothesis 2 assumes that certified organic farmland is in fact working as a counterforce to the environmental hazardous effects of agriculture and reducing water pollution such as biochemical oxygen demand.

## 6. Methods

To test our hypotheses we use a fixed-effects panel regression (for nations where sufficient data is available) including time dummies with robust standard errors adjusted for clustering by nation from 2002–2007. A fixed-effects panel model with time dummies controls for any unobserved, time-constant features particular to each nation, as well as events factors that change over time but that do not vary across nations, such as international commodity prices.

The logic of our modeling approach is based on the STIRPAT framework [35–43]. STIRPAT was first developed by Dietz and Rosa [44] as a reformulation of the popular IPAT equation to gauge how population (P), economic growth or affluence (A), and technology (T) affect the scale of environmental impacts (I). STIRPAT is a stochastic model that assumes environmental impacts are a multiplicative function of population, affluence, and technology, but does not assume that each factor has a proportional effect, STIRPAT thereby allows for hypothesis testing. In STIRPAT analyses each variable is converted to natural logarithmic form, since an additive model with logarithms is equivalent



to a multiplicative model with variables in original units. STIRPAT is therefore an elasticity where beta coefficients represent a proportional rate in the dependent variable (here environmental impact) for every one-percent change in the independent variable corresponding to the beta coefficient [41,43]. The fixed-effects model specification is therefore:

$$\ln y_{it} = \beta_1 \ln(x_{it}) + \beta_2 \ln(x_{it}) \dots \beta_k \ln(x_{itk}) + \mu_i + w_t + e_{it}$$

Here the subscript  $i$  represents each unit of analysis (nation) and the subscript  $t$  the time period,  $y_{it}$  is the dependent variable in original units for each nation at each point in time,  $x_{itk}$  represent the independent variables in original units for each nation at each point in time,  $\beta_k$  represents the elasticity coefficient for each independent variable,  $\mu_i$  is a nation specific disturbance term that is constant overtime (*i.e.*, the nation specific  $y$ -intercept),  $w_t$  is a period specific disturbance term constant across nations, and  $e_{it}$  is the stochastic disturbance  $e$  term specific to each nation at each point in time. Our model is specified below:

Biochemical oxygen demand $_{it} = \beta$ population $_{it} + \beta$ GDP per capita $_{it} + \beta$ percent urban population $_{it} + \beta$ percent organic hectares of total agricultural land $_{it} + \mu_i + w_t + e_{it}$

## 7. Dependent Variable

In this study, water pollution is the dependent variable and a proxy for environmental degradation. We measure water pollution via biochemical oxygen demand (BOD) (in thousands of kilograms per day) which is the amount of oxygen microorganisms in water needed to break down waste in natural water systems. Organic material in water comes from a variety of sources, such as plant, animal, and/or human waste and industrial activities. While the organic materials are in the water, metabolic processes of bacteria break down the waste over time [44]. During these process, a certain amount of dissolved oxygen is consumed. BOD measures the amount of oxygen consumed by microorganisms to decompose waste. Waters with high amounts of waste correspond to a high BOD because a large number of microorganisms are necessary to breakdown the waste. High BOD rates put other aquatic life at risk due to reduced oxygen availability. Nitrates and phosphates are important elements that contribute to the amount of BOD found in natural water systems [44]. BOD measurements are one of the most reliable pollution indicators because it is relatively inexpensive to measure. In addition, BOD measurements are traditional starters for industrial pollution control within nations and are widely used in across nations [25]. Our data for BOD comes from the World Bank's environmental indicators website [45]. The World Bank's data on BOD started as continuation of Hettige *et al.* [25] attempts to measure the amount of industrial pollutants found in natural water systems globally. To achieve this, the authors gather data on BOD levels in natural water systems from multiple nations, when/where data was available. The World Bank continued this aggregation through 2007.

## 8. Key Independent Variable

Our key independent variable in this analysis is proportion of organic farmland, which estimates the amount of the organic hectares divided by the total farming hectares. The data for organic agricultural land was obtained from Organic World Statistics [46]. Data on certified organic agriculture is obtained from the SOEL/FiBL/IFOAM survey. Certified organic farming refers to both the certified in conversion areas and the certified fully converted areas. A major drawback of this data is that definitions of organic may vary across countries and data are gathered using various methods (*e.g.*, surveys, secondary data, experts, *etc.*) thus we interpret the results presented here cautiously.

## 9. Additional Independent Variables

GDP per capita is a control variable to account for a country's economic standing and was gathered from the World Bank [45]. The variable was measured in constant 2005 US dollars. GDP per capita is a standard control variable for most environmental impacts analyses. Environmental

sociological theories of the treadmill of production and world-systems suggest economic development to be a major structural driver of environmental degradation [43]. Previous research on water pollution, ecological footprints, carbon dioxide emission, and energy consumption find GDP per capita to be a positive predictor [25,38–43,47] (Earlier models not shown here were estimated with a quadratic term for GDP per capita and urbanization, however neither was found significant in a two-tailed test).

Population and urbanization are additional control variables representing important national demographic factors and were collected via the World Bank. Previous research on nature/society have found population to be a significant factor [39–43,47]. Urbanization is included as a control variable to evaluate the level of a country's urbanization. Number of persons living in urban areas is estimated as the total persons living in urban areas divided by the total population. Additionally, we included urbanization as a control variable to serve as a proxy for the number of sewage systems and industrial processes that contribute to BOD [25]. Prior research has shown urbanization to be a significant predictor for environmental impacts. Table 1 includes a summary of descriptive statistics for all dependent and independent variables.

**Table 1.** Descriptive statistics of variables in raw form.

Variables	Mean	Standard Deviation	Minimum	Maximum
Biochemical oxygen demand	234,006.8	774,215.3	131.9	8,800,000
Proportion organic land	0.1	1.4	0.00003	14.5
Population	$3.67 \times 10^7$	$1.16 \times 10^8$	87,276	$1.30 \times 10^9$
GDP per capita	11,297.4	12,804.6	118.1	74,220.4
Percent urban population	61.4	20.8	11.6	100

Note: N = 274.

## 10. Results

As noted above, the fixed-effects models presented below control for omitted factors that vary cross-nationally but are temporally invariant, such as geographic, climatic, and geological factors, as well as the effects of the historical legacy preceding the periods examined here (e.g., the era during which a nation began to industrialize agriculture). The models, therefore, control for temporally invariant characteristics unique to each nation. Additionally, the models control (via the time dummies) for cross-sectional invariant factors that change over time, such as international prices of resources. Thus, these models focus on change over time within nations, not on cross-sectional differences. All variables (except dummy variables) are in natural logarithmic form, which makes this an elasticity model.

The results from our analysis are reported in Table 2. We present R-squared within and the highest variance inflation factor (VIF) for each model. Within R-squared measures the variation of BOD within countries explained by the independent variables. In fixed-effect panel analyses, R-squared within is a better measurement than R-squared overall because fixed-effects disregards between unit variation [40]. The variance inflation factor measures the amount of multi-collinearity, note that none of our independent variables reached a VIF of 10 or higher. This means that our coefficients are not substantially affected by a collinear relationships [48].

Our results show support for H1, (although they do not confirm it) which provides evidence for our theoretical assumption that global conventionalization of organic farming is increasing, not reducing agriculture's metabolic rift with respect to water ecosystems. Specifically our model demonstrates that as a country's organic land increases there is a corresponding increase in BOD while holding constant population, urbanization, and GDP per capita, indicating that the rift of water pollution in the water cycle is enhanced through organic farming. It is important to note that our coefficient for proportion organic farmland is close to zero, meaning that organic farming may have a significant but negligible effect on BOD. Of course, importantly, the coefficient is not negative, clearly

ruling out H2. While these results support our theoretical assumptions, they must be understood with caution as they do not assess the specific types of practices conducted on organic farms.

**Table 2.** Fixed-effects panel regression coefficients predicting Biochemical Oxygen Demand.

Independent Variables Logged	Coefficients (SE)
Population	1.308 *** (0.467)
Percent urban population	1.032 * (0.438)
GDP per capita squared	0.169 ** (0.054)
Proportion organic land	0.018 *** (0.003)
R-squared within	0.266
High VIF	1.003
N	277

\*  $p < 0.05$ ; \*\*  $p < 0.01$ ; \*\*\*  $p < 0.001$  (two-tailed tests).

Population, GDP per capita, and urban population were also found to be significant predictors on BOD, which is consistent with the findings of previous STIRPAT analyses [35–43]. Specifically we find that a one percent increase in GDP per capita corresponds with a .169 percent increase in BOD. We also find that a one percent increase in population results in a more than 1.3 percent increase in BOD, indicating that there an elastic relationship between BOD and population. Similarly, we find that a one unit increase in the percent of urban population corresponds to a one percent increase in BOD, meaning that not only is population a powerful contributor to BOD but specifically urban population. Previous research on BOD found similar results from control variables [47].

Our results support the findings of soil scientists who have found that specific organic management practices lead organic farms to have higher or similar levels of nitrate leaching as conventional farms [10,12,13,27]. Additionally our results support the findings of social scientists who argue that organic farming is becoming increasingly reliant on non-farm inputs such as organic fertilizers [6–8,16–19]. However, these results may also suggests that shifts toward organic farming are correlated with BOD but have not increased enough to counteract the amount nitrate leaching that occurs from conventional farming.

## 11. Discussion and Conclusions

Here we have reviewed literature that argues certified organic farms are becoming increasingly reliant on non-farm inputs, such as organic fertilizers [6–8,16–19], as well as literature demonstrating that some organic farming practices contribute to nitrate leaching [10,12,13,27]. We have also reviewed literature demonstrating how nitrate leaching contributes to water pollution and can increase the biochemical oxygen demand in natural water systems. Although shifting agricultural land toward organic land has the potential to reduce levels of BOD, due to specific organic management practices that limit the use of non-farm inputs, we have found that between 2002 and 2007 increasing the proportion of organic farmland has not reduced BOD. Specifically, we have measured the average rate per day of BOD in natural water systems within countries and have found that increasing the proportion of organic farmland increases BOD levels.

To better interpret this finding, we use the theory metabolic rift and argue that the conventionalization of organic farming reproduces industrial agriculture's rift with water ecosystems. Specifically, we contend that the increased use of non-farm inputs to maintain soil fertility on organic farms replicates conventional agriculture's metabolic rift, and as a result, the development of organic



farming over time has only increased water pollution rather than reduce it. These results do not mean that shifting agricultural production toward organic practices will never reduce water pollution, however they do demonstrate a potential problem in current trends within the organic sector of the agricultural industry. Social science research conducted in different nations has found that over time new farmers participating in the organic industry are less cognizant of on-farm practices that maintain soil fertility and limit the necessity of agro-inputs [8,16,18]. This trend must be addressed if organic farming is going to be a sustainable alternative to conventional agriculture and limit water pollution. We believe future regulations aimed at reducing water pollution from agricultural production should address both the natural and social context in which agricultural systems progress in order to develop a more environmentally sustainable agricultural system.

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**Author Contributions:** Julius Alexander McGee conceptualized and designed the research. Julius Alexander McGee and Camila Alvarez wrote the paper and analyzed the data. Both authors have read and approved the final manuscript.

**Conflicts of Interest:** The authors declare no conflict of interest.

## Appendix

**Table A1.** Summary of countries and years.

Country	Year					
Albania	-	-	-	2005	2006	-
Argentina	2002	-	-	-	-	-
Austria	2002	2003	2004	2005	2006	-
Azerbaijan	-	2003	2004	2005	2006	2007
Belgium	-	-	2004	2005	2006	-
Bulgaria	2002	2003	2004	2005	2006	2007
Chile	2002	2003	2004	2005	2006	-
China	-	2003	2004	2005	2006	2007
Colombia	2002	2003	2004	2005	-	-
Croatia	2002	2003	2004	2005	2006	2007
Cyprus	2002	2003	2004	2005	2006	2007
Czech Republic	2002	2003	2004	2005	2006	-
Denmark	2002	2003	2004	2005	2006	-
Ecuador	2002	2003	2004	2005	-	-
Estonia	2002	-	2004	2005	2006	2007
Fiji	2002	2003	2004	-	-	-
Finland	2002	2003	2004	2005	2006	-
France	2002	2003	2004	2005	2006	-
Germany	2002	2003	2004	2005	2006	-
Greece	-	-	2004	2005	2006	-
Ghana	-	2003	-	-	-	-
Hungary	2002	2003	2004	2005	2006	-
Indonesia	-	2003	2004	2005	2006	-
Iran	2002	-	-	2005	-	-
Ireland	2002	2003	2004	2005	2006	-
Israel	2002	2003	-	-	-	-
Italy	2002	2003	2004	2005	2006	-
Japan	2002	2003	2004	2005	-	-
Jordan	-	-	-	2005	2006	2007
Kazakhstan	-	-	2004	2005	2006	2007
Kyrgyz Republic	-	-	-	-	-	2007
Latvia	2002	2003	2004	2005	2006	2007
Lithuania	2002	2003	2004	2005	2006	2007
Luxembourg	2002	2003	2004	2005	2006	-

Table A1. Cont.

Country	Year					
Macedonia, FYR	-	-	-	-	2006	2007
Madagascar	-	2003	2004	2005	2006	-
Malaysia	-	2003	-	-	2006	-
Malta	-	-	-	2005	-	-
Mauritius	2002	2003	2004	2005	2006	2007
Morocco	2002	2003	2004	2005	2006	2007
Netherlands	2002	2003	2004	2005	2006	-
New Zealand	2002	2003	2004	2005	2006	2007
Norway	2002	2003	2004	2005	2006	-
Pakistan	-	-	-	-	2006	-
Panama	-	-	2004	2005	-	-
Paraguay	2002	-	-	-	-	-
Philippines	-	2003	-	2005	-	-
Poland	2002	2003	2004	2005	2006	-
Portugal	2002	2003	2004	2005	2006	-
Romania	2002	2003	2004	2005	2006	2007
Russian Federation	2002	2003	2004	2005	2006	2007
Saudi Arabia	-	-	-	-	2006	-
Slovak Republic	-	-	-	-	2006	-
Slovenia	2002	2003	2004	2005	2006	2007
South Africa	2002	2003	2004	2005	2006	2007
South Korea	2002	2003	2004	-	2006	-
Spain	2002	2003	2004	2005	2006	-
Sri Lanka	-	-	-	-	2006	-
Sweden	2002	2003	2004	2005	2006	-
Syrian Arab Republic	2002	2003	2004	2005	2006	2007
Tanzania	-	2003	2004	2005	2006	2007
Thailand	2002	-	-	-	2006	-
Turkey	2002	2003	2004	2005	2006	-
Ukraine	-	2003	2004	2005	2006	2007
United Kingdom	2002	2003	2004	2005	-	-
United States	2002	-	2004	2005	2006	-
Vietnam	-	2003	2004	2005	2006	2007

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