The Journal of Environment & Development

http://jed.sagepub.com

Biodiversity and Socioeconomic Impacts of Selected Agro-Commodity Production Systems

Jan Joost Kessler, Trudy Rood, Tonnie Tekelenburg and Michel Bakkenes

The Journal of Environment Development 2007; 16; 131

DOI: 10.1177/1070496507302516

The Journal of Environment & Development
Volume 16 Number 2
June 2007 131–160

10.1177/1070496507302516
http://jed.sagepub.com
hosted at
http://online.sagepub.com

Biodiversity and Socioeconomic Impacts of Selected Agro-Commodity Production Systems

Jan Joost Kessler
AIDEnvironment, Amsterdam
Trudy Rood
Tonnie Tekelenburg
Michel Bakkenes
Netherlands Environmental Assessment Agency, Bilthoven

This study assesses the socioeconomic and biodiversity impacts associated with the production of selected agro-commodities in their production countries and areas. Selected agro-commodities are soy (in Argentina and Brazil), palm oil (in Indonesia and Malaysia), beef (in Argentina and Brazil), and coffee (in Honduras and Vietnam). In each of the countries specific production areas and regions were selected, where production of the agro-commodity has shown strong expansion during the last 5 to 8 years. Using data and information on biodiversity and socioeconomic indicators available at the subnational level, a loss of biodiversity as well as a decline of critical socioeconomic indicators was observed in 54% of the studied production areas. Because in the mid-1990s several production areas had lower values for important socioeconomic indicators compared to the national average, a widening of the gap between the socioeconomic situation in production areas as compared to the national average was found in 26% of the cases studied. This corresponds to 59% of areas with a poor initial development situation. We found that factors explaining these patterns are characteristics of the commodities, macroeconomic and governance issues of the countries, as well as the history of the production area and whether production increase occurs through frontier expansion or intensification. Overall these results contradict the neoliberal assumption that export-oriented development will generally stimulate economic growth and reduce poverty in the production areas.

Keywords: *sustainability impacts; integrated assessment; biodiversity; poverty reduction; agro-commodities; trade; soy; palm oil*

Introduction

Trade and Sustainable Development

Sustainability was originally an ecological concept. In 1972 the report *Limits to Growth* focused on the use of the environment and nature by future generations (Meadows et al., 1972). The World Commission on Environment and Development related issues of environment, world trade, poverty and economic development, and North–South relations. It established the link between sustainability and development in the report *Our Common Future* (Brundtland Commission, 1987). An oft-quoted definition of sustainable development is: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." The World Bank was partly responsible for a broader definition of sustainability in which decline of natural capital was deemed acceptable if compensated by growth of economic or sociocultural capital (e.g. Atkinson & Pearce, 1993; Pearce, 1993).

Human development throughout history has depended on sustainable access to natural resources (Hopfenberg & Pimentel, 2001; de Vries & Goudsblom, 2002). On the basis of the traditional (Ricardian) comparative advantages, global trade has allowed societies to take advantage of differences in local supply, spatial concentration and specialization, and to overcome regional limits to sustainable consumption levels. Stimulating global trade is part of the neoliberal agenda, represented by a gamut of policies promoting economic growth in many parts of the less-developed world. It is argued that various free market-oriented economic policy prescriptions will help develop a nation's economy. However, there does not seem to be a significant relationship between export growth and poverty reduction (UNCTAD, 2002, 2004). In many of the least developed countries (LDCs) with increasing export orientation, poverty rates actually increased in the 1990s.

There is increasing understanding of the trade-offs of global trade. In most cases extractive industries and economic activities in the primary sector are associated with increasing South–North material flows. Considering the limited power of Southern countries on world markets and the falling prices of primary commodities, export revenues in producer countries can be maintained only through an increase in the volume of export (Giljum & Eisenmenger, 2004). The extractive industries and economic activities in the primary sector associated with increasing South–North material flows lead, in most cases, to higher environmental pressures (UNEP, 1999, 2005). The main problem is that of unequal conditions of exchange in which the production partners have little choice but to exploit and possibly exhaust their natural resources, whereas the consumption partners may maintain high environmental quality within their own borders (Giljum & Eisenmenger, 2004). This can be demonstrated by the fact that reduced environmental pressures in some countries, according to the green Kuznets curve (Yandle, Bhattarai &

Authors' Note: This article reflects a study undertaken by the Netherlands Environmental Assessment Agency (MNP) and AIDEnvironment. Most of the research by AIDEnvironment was carried out by Irene de Bruin; the help provided by Maarten Dros in the design and analysis of the study was highly appreciated. We would also like to thank two reviewers for their useful and critical comments. Address correspondence to Jan Joost Kessler, AIDEnvironment, Donker Curtiusstraat 7-523, 1051 JL Amsterdam, the Netherlands, E-mail: kessler@aidenvironment.org

Vijayaraghaven, 2004), took place in the global context of ever-increasing environmental pressures (Faaij, Minnesma & Wiesczorek, 2003) and reduced biodiversity (MNP, 2006).

Towards a Comprehensive Impact Assessment of Commodities

In order to assess the environmental impacts of global trade and high levels of consumption in wealthy countries, one approach has been the "ecological footprint" model (Wackernagel & Rees, 1996; Wackernagel et al., 2002). This model converts environmental impacts into spatial units. However, this model has been severely criticized as being too simplistic (e.g. van den Bergh & Verbruggen, 1999; Opschoor, 2000; van Vuuren & Bouwman, 2005). It is argued that using the ecological footprint concept to assess environmental impacts has methodological flaws, such as the aggregation method for land and energy use, involving a rather arbitrary weighting.

In order to overcome these weaknesses, the Netherlands Environmental Assessment Agency (MNP) developed a systematic method to assess the impacts of consumption on global biodiversity, referred to as the ecological claim (Rood et al., 2004). The effects of consumption were determined on land use, energy use, greenhouse gases, and nitrogen deposition. Land use per capita was calculated using local yields. In this way, differences between consumption in various world regions were made clear. For example, total land use per capita differs just as sharply among world regions as land use for animal products, crops, and biofuels (Van Vuuren & Bouwman, 2005).

The ecological claim determines the impacts on biodiversity from different types of land use, taking into account their area and intensity of resource use. In doing so, the impact of Dutch consumption on global biodiversity was calculated as being equal to an area with a total loss of biodiversity of about 120,000 km^2 (Rood & Alkemade, 2005). This is three times the total surface of the Netherlands. The production and consumption of food and wood products were found to be the most important factors for the Netherlands in causing global biodiversity loss. Many of these primary commodities are imported from Southern countries.

However, another important criticism to the ecological footprint method is the fact that it does not recognize the existence of comparative advantages and specialization. It can therefore be characterized as being biased against trade (van den Bergh & Verbruggen, 1999). The question also arises whether comparative advantages in terms of natural resources (natural capital) are used effectively to build up human and physical capital, and thus meet the broader requirements and expectations of sustainable development. Thus, there is need for a more comprehensive approach that looks at the three dimensions of sustainable development: social, economic, and environmental. Negative environmental and biodiversity impacts should be put in the perspective of improving economic and social conditions in producer countries.

The research documented in this article looks at the impacts of global production and trade of agricultural commodities on the three sustainable development dimensions, and the trade-offs between these dimensions.

Objectives

Our research objectives were geared to: (a) develop a method to assess impacts of South–North resource flows in their production regions on sustainable development dimensions, and (b) assess reliable insights into the socioeconomic and biodiversity impacts of selected agro-commodities in producer countries. The hypothesis is that loss of biodiversity for export-oriented agro-commodity production contributes to economic growth, improved social welfare, and poverty reduction in production areas, which would support the view that trade stimulates development. The study focused on agro-commodities with recent expansion in trade volumes.

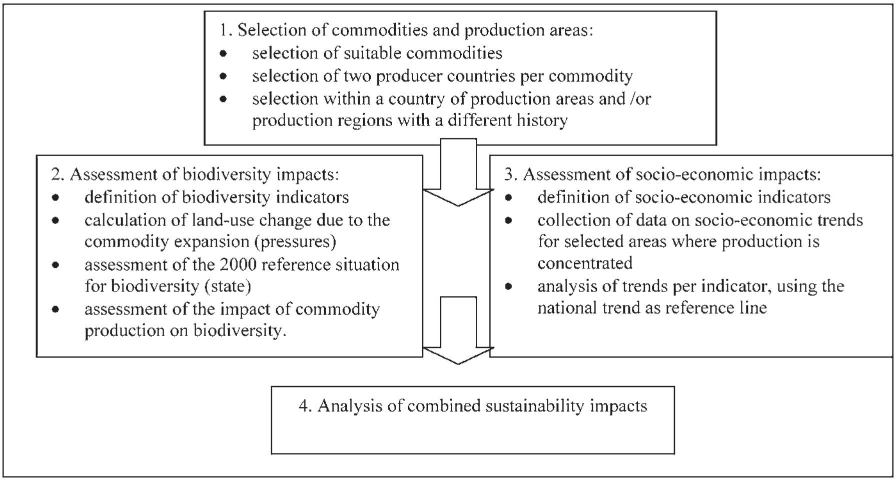
Method

Introduction and Overview

The method has an exploratory character as it combines different disciplines and sustainable development perspectives within one comprehensive approach. It also has to deal with the challenge to obtain reliable data about recent environmental and socioeconomic changes, demonstrate the linkages and attribute changes to selected commodity production dynamics. Thus, there was need to specify relevant indicators, the time frame, and an assessment scale that captures the key dynamics within the production areas. Before going into details on the method, the spatial focus and time scale are explained.

There is a problem of ecological (ecosystem) boundaries not coinciding with socioeconomic (administrative) development units, and accordingly different spatial scales for relevant indicators. Our analysis is therefore based on relatively large administrative units, and ecological units were adjusted to create a best fit. The spatial focus can best be characterized as a meso-level approach, corresponding to administrative units referred to as states, departments, regions, or provinces. Many studies dealing with environmental and socioeconomic impacts of production processes focus on either the macro-level (using statistical data and establishing correlations between parameters) or the micro-level (e.g. case studies, detailed household surveys). Both approaches have limitations: national statistical data are in most cases too broad to attribute changes to specific sectors or commodities, while local case studies usually do not provide insights into important dynamics such as migration, competitiveness, rural–urban relations, and land-use changes. Whereas statistical data at national level are, in general, collected on an annual basis, detailed

Figure 1
Adopted assessment method comprising four steps.



case studies usually have an incidental character. This study aimed to overcome the limitations of both approaches, with statistical data from the subnational level.

We selected commodities that have shown recent and rapid expansion. The study period covers (part of) the recent expansion period for the selected commodities. In most cases this is from the mid-1990s to the early 2000s, covering a period of 5 to 8 years. This period varies for the selected countries, as a result of the variable availability of statistical data.

The method developed for this research shows four steps (Figure 1), which will be explained in more detail below.

Step 1: Selection of Agro-Commodities and Production Areas

Suitable combinations of agro-commodities and production areas were selected as follows:

- Selection of agro-commodities. A long-list was made of 20 agro-commodities that have shown rapid increase in global trade volume during recent years. From that list, agro-commodities were selected for which data about biodiversity impacts are available (Rood et al., 2004). For practical reasons, not more than four were selected for this exploratory research.
- Selection of countries. For the selected four commodities, the main Southern production countries were listed. Countries were selected for which the selected commodities have a relatively large economic value and recent expansion of production volume. Second, countries were selected on the basis of availability and access to socioeconomic statistics.

Within the selected countries, the production of the selected agro-commodities is in most cases concentrated in certain areas, which can be associated with administrative units at the subnational level. In order to be able to attribute possible changes in environmental and socioeconomic indicators to the agro-commodity production process, there is need to focus on areas where production is concentrated. The production areas were selected on the basis of the following criteria: (a) high importance in the area of the agro-commodity in terms of production volume, and (b) recent expansion and high importance of the agro-commodity for the economy in the area.

The agro-commodity production process in these selected areas shows variation in terms of history (some areas having a long tradition of producing the commodity and others showing only recent introduction) and intensity of production. Environmental and socioeconomic impacts may vary according to these variables. Where possible, we therefore grouped production areas into three types of production regions:

- "Established" region, that is, where the agro-commodity has been produced for a relatively long time and limited expansion has taken place during the study period.
- "Expansion" region, that is, where strong expansion of the agro-commodity has occurred, at the expense of agricultural lands and natural ecosystems, but expansion started before the study period.
- "Frontier" region, that is, where strong expansion of the agro-commodity has occurred, which started only recently, during the study period, and which is taking place largely at the expense of natural ecosystems (mainly forests).

Step 2: Assessment of Biodiversity Impacts

The two main causes of biodiversity loss are conversion of natural ecosystems into agricultural or other land use (loss of ecosystem quantity/area), and the decline of species distribution and abundance in ecosystems due to degradation processes such as logging, pollution, disturbance, and fragmentation (loss of ecosystem quality). Biodiversity loss is defined as a change due to human interventions, as natural changes of biodiversity are a much slower and longer-term process. Many indicators exist for measuring the diversity of species, ecosystems, and genes, such as species richness indicators and the Red List Indicator, but their applicability at large scales and in impact assessments is limited (Ten Brink, 2000).

The Natural Capital Index (NCI) or Mean Species Abundance (MSA) combines the two above main causes of biodiversity loss in one index and was first applied in the Global Environmental Outlook 3 (GEO3) (UNEP, 2002; Potting & Bakkes, 2004). The NCI reflects biodiversity loss as a process of homogenization (McKinney & Lockwood, 1999) by which a few species, adapted to landscapes influenced by human activities, become more common and many species become rare, eventually leading to extinction of some species. The NCI can be considered as proxy for the indicators agreed upon in the Convention on Biological Diversity (CBD) (UNEP, 2004). The NCI concept is similar to the biodiversity integrity index of Majer and Beeston (1996), and the Biodiversity Intactness Index of Scholes and Biggs (2005). Both indices calculate differences in biodiversity relative to a pristine or undisturbed reference situation, but differ from the NCI in their weighting factors.

The NCI is calculated with the global biodiversity model GLOBIO 3 (Alkemade et al, 2006), which combines the effects of the land use changes (land use intensity, infrastructure, climate change, nitrogen deposition, and fragmentation) on the mean abundance of selected species relative to an original, undisturbed situation. Central in calculating the NCI is a set of regression equations relating the degree of pressure to the degree of impact (dose–response relationships), if possible for each relevant combination of biome and continent. These equations were based on various studies, of which there were 120 on the relations between species diversity and land use types, 50 on the effect of nitrogen deposition, and 309 on infrastructure effects. In this study we used the estimates of NCI from GLOBIO 3. The database in the model includes two different measures: mean species abundance and species richness of the original wild species, each in relation to different degrees of pressure. An NCI of 100% indicates an undisturbed situation with intact original biodiversity (pressures do not exceed set thresholds). As a result of agricultural land use intensity biodiversity declines: 50% NCI for agroforestry systems, 30% NCI for extensive agriculture, 10% NCI for intensive agriculture, and 5% NCI for irrigated agriculture (Alkemade et al., 2006; Reidsma, Tekelenburg, Van den Berg & Alkemade, 2006).

The indicators used in this study were defined on the basis of the NCI biodiversity indicator framework and GLOBIO 3 model (shown in Table 1). The pressure indicator B1 is the relative increase of the commodity production area within the study period as compared to the original production area. The second state indicator B2 refers to the ratio of biodiversity (NCI) in the production area and the national average. The year 2000 was chosen because of land use data availability in the Global Land Cover dataset of 2000. The impact indicator B3 indicates to what extent biodiversity loss has occurred as a result of the commodity expansion during the study period and is expressed in terms of percent NCI loss. It was based on the effects of habitat change and changes in land use intensity. The values are conservative estimates because additional effects of pollution and disturbance could not be assessed at the local scale. The impact indicator B4 gives insight into the relative contribution of the commodity to biodiversity loss, and is obtained by dividing indicator B3 by the state of biodiversity in the production region (NCI value in the year 2000). The ecological claim on biodiversity (Rood et al., 2004) indicates overall biodiversity loss. It is calculated by multiplying the area with commodity development with the average biodiversity loss, taking into account original land use and the multiplier effect, and is expressed in terms of area (impact indicator B5).

In the assessment of the biodiversity impacts of commodity production, we took into account original land use and biodiversity before commodity production.

Table 1
Indicators Used to Assess Biodiversity Impacts

Indicators	Description of Relevance
B1. Relative increase of commodity crop area (growth factor)	The area of commodity production will vary according to situations of "boom or bust." This indicator indicates the ratio between commodity area increase in the study period and the original production area.
B2. Biodiversity in the production area compared to the national average	We expect commodity development to be concentrated in natural habitats with high productivity. This indicator calculates the NCI in 2000 (taking into account different types of land use) in the production areas as compared to the national average. NCI describes the mean species abundance relative to the undisturbed situation.
B3. Loss of biodiversity due to the commodity	We expect commodity development to cause losses of natural habitats and land use changes. This indicator calculates NCI loss in the study period as a result of the commodity expansion. Indirect effects (pollution and disturbance) were not addressed.
B4. Relative contribution of the commodity to overall biodiversity loss	We expect a high contribution of commodity development to the total biodiversity loss. This indicator calculates NCI loss by the commodity within the study period as a proportion of overall NCI decline due to land use changes.
B5. Ecological claim (overall biodiversity loss)	We expect more insight in the magnitude of the biodiversity losses when expressed in square kilometers. This indicator calculates loss of biodiversity from natural ecosystems with intact biodiversity, with corrections for the original land use and multiplier effects.

Impact is high in case of conversion of intact forest ecosystems (at least 80% NCI loss). Impact is lower when natural grasslands are converted (30% NCI loss) or existing extensive crop lands are converted into monocultures (20% to 0% NCI loss) (Alkemade et al., 2006; Reidsma et al., 2006). We assessed the origin of the land occupied by the commodity in three categories: natural ecosystems, extensive land use (including pasturelands), and intensive land use. We also took into account two multiplier effects at the macro level: additional deforestation by immigrants attracted by the commodity production, and land clearing by people displaced from their original lands. This was done on the basis of reports and interviews with experts and by using area requirements per household for extensive agricultural land use.

A number of assumptions had to be made for the beef commodity, to be able to convert estimates of beef production to number of cattle and pastureland area. To do so we took into account livestock management systems and conversion being high in recent expansion areas and lower in populated areas. These data should be treated with more caution than for the other commodities.

Table 2
Indicators Used to Assess Socioeconomic Impacts

Indicators	Relevance and Description
E. Economic	
E1. Per capita gross domestic product (national and administrative units)	An increase of GDP per capita is expected in production areas. GDP per capita is corrected for inflation. In some cases GDP per capita was calculated as based on recent population and GDP statistics.
E2. Employment rate	An improved employment rate is expected in production areas. Where possible a distinction was made between rural and urban employment.
S. Social	
S1. Food security, child mortality	Food security may be negatively affected due to the replacement of food crops by commodity export crops. Child mortality can be used as a proxy for food security.
S5. Poverty (index)	Reduced poverty rate is expected in the production areas, as associated with improved incomes. The Human Poverty Index (HPI) is an index measuring shortages in life expectancy, education, and standard of living.
V. Vulnerability	
V1. Conflicts	There are accounts of conflicts due to land grabbing, illegal practices, etc. as a response to rapid expansion of production volumes. Other indications for conflicts are local corruption and cases of slavery or child labor.
V2. Inequality	Equality in income distribution may decline if few benefit from the production process, but trickle down and increased employment may improve inequality. A measure used for inequality is the GINI Index.

Step 3: Assessment of Socioeconomic Impacts

A long-list was made of social and economic issues expected to be influenced by the production process and related environmental changes. Next, priorities were set and search was done to identify human development indicators that could be linked to these issues. This resulted in a short-list of the six most relevant indicators (Table 2). For most of these, quantitative values are available from UNDP Human Development reports, ILO reports, and national government statistics. Definitions of the indicators used were also derived from these sources. Case studies were used to understand underlying production systems and cause–effect chains. Vulnerability is defined in accordance with the livelihoods approach as the external factors that influence security of producers. Inequality is considered as a proxy indicator for vulnerability as it refers to the gaps between social groups in terms of access to incomes and production assets. For both the number of conflicts and inequality, in several countries no quantitative data were available. In that case, trends could not be established, but an attempt was made to assess in a qualitative way whether in the selected production areas the incidence of conflicts or the level of inequality is different from the average national situation.

The aim of the study was to draw conclusions about the relative contribution of agro-commodity production to socioeconomic development in the selected production areas, and thus to assess socioeconomic impacts of agro-commodity production. To do so, indicator values and trends during the study period in the selected production areas were compared with average indicator values and trends at the national level, in terms of:

- Starting value of the indicator (at the start of the study period, i.e. the mid-1990s) in the production area as compared to the national average. The starting value may be worse (lower value in production area as compared to national average), better, or similar/variable.
- The indicator changes or trend during the study period in the production area as compared to the average rate of change at the national level. The rate of change may be favorable (more positive or less negative trend in production area as compared to national average trend), unfavourable, or similar/variable.

Step 4: Analysis of Combined Sustainability Impacts

The analysis of the combined impacts of the selected commodities is based on the comparison of decline of biodiversity (as assessed by the five NCI indicators) with the socioeconomic changes in the production areas (assessed by six socioeconomic indicators). The aim of these comparisons is to find out whether production areas or regions with a loss of natural capital (for the benefit of the commodity production process) perceive socioeconomic benefits. There are basically four possible patterns, as outlined in Table 3 below.

In Table 3, situations 3 and 4 refer to production areas where the starting values of the selected socioeconomic indicators are worse than the national average, while situations 2 and 4 refer to unfavorable changes during the study period. Because of expected economic benefits, and in line with the hypothesis to be tested (see the Introduction), favorable changes are expected, meaning that the trend is more positive (or less negative) in the production area as compared to the national average trend. As a result, there would be a "closing the gap" that existed between the production areas and the national average before commodity production was stimulated (situation 3). If the gap would widen because of an unfavorable trend (situation 4), this would mean that the hypothesis is incorrect and one could speak of "widening the gap."

Three analytical considerations will now be discussed. First, it is possible that the production area shows an unfavorable rate of change in spite of a positive trend, because it cannot keep pace with the (stronger) national development trend. This may be the case if the country shows strong industrialization. A correction is therefore needed in case the national economic development trend is strongly influenced by another commodity or industrial development. Therefore, the relative importance

Table 3
Interpretation Framework for Socioeconomic Impact Patterns

	Starting Position in Production Area Compared to National Average	
Rate of change in production area compared to national average	Better or Similar	Worse
Favorable or similar	1. *Expanding advantage*. The production area expands its advantage, possibly due to the commodity.	3. *Closing the gap*. The production area is showing positive development, probably through benefits from the commodity.
Unfavorable	2. *Reducing advantage*. The production area loses its advantage, in spite of commodity production.	4. *Widening the gap*. The production area does not benefit enough from commodity production, so that the gap widens.

of the primary sector to the gross domestic product (GDP) was also indicated, at the national level and within the selected production areas.

Second, it has been suggested that control sites should be identified, for instance comparable areas where the agro-commodity is not produced, or where the commodity is produced but not traded. This should allow one to draw firmer conclusions regarding the relative contribution of the commodity production process to the assessed changes. However, this suggestion meets practical constraints, because areas where the commodity is not produced or not traded either do not exist (because high market demand in recent years has caused all suitable areas to be occupied and products traded) or are not comparable to the selected areas (being more remote, less suitable, less productive, or unsafe).

Third, more sophisticated analytical approaches have been proposed, such as multivariance analysis or regression analysis. This option has not been adopted because of the existence of critical gaps in the data set (due to poor availability of statistical data in some countries).

Results and Analysis

The Data Set

Using the selection criteria as outlined above, four commodities were selected and for purposes of comparison, two producing countries for each product (Table 4). In all countries the selected commodities have shown rapid increases in export volumes during recent years (the only exception being beef from Argentina) and the two

Table 4
Exports of Selected Commodities From Selected Countries for This Study

	Mid-1990s	2003		Mid-1990s	2003
Soy (Mtonne)			Meat (Ktonne)		
Export Brazil	16.8	36.5	Export Brazil	140	780
Export Argentina	11	33	Export Argentina	297	329
Palm oil (Ktonne)			Coffee (Ktonne)		
Export Indonesia	2,082	9,862	Export Honduras	99	162
Export Malaysia	6,643	10,886	Export Vietnam	391	749

selected countries together constitute a major proportion of global trade: 84% for palm oil from Indonesia and Malaysia, 46% for soy from Brazil and Argentina, 30% for beef from Brazil and Argentina, and 17% for coffee from Vietnam and Honduras (Honduras representing a rapidly growing niche market).

Within the selected countries, specific production areas were selected, and regions were identified with a different history and intensity of the commodity production for the combinations of soy–Brazil, soy–Argentina, palm oil–Indonesia, and palm oil–Malaysia (see Methods, step 1). For coffee and beef this distinction was not possible and the selected production areas were grouped within one category of "all areas" (Table 5). In total, data were collected for 34 administrative units at the meso level. Biodiversity indicators were assessed as explained in the Methods, step 2. Socioeconomic data were collected for at least 2 years, one in the mid-1990s and one in the early 2000s, thus covering the study period and allowing one to establish trends. However, in some cases indicator values were missing. In total about 800 social and economic indicator values were collected. The detailed results are presented in a 200-page report (Kessler, Dros & de Bruin, 2005) which can be obtained from the authors. In this article we present the results of the analyses of these socioeconomic data.

Biodiversity Impacts

Table 6 provides an overview of the biodiversity impacts per commodity, per country, and for the selected production areas per country for the five selected biodiversity indicators. First, one may look at area expansion due to commodity development (column 1). The expansion of the four selected commodities in the selected production areas during a period of 5 to 8 years was responsible for the use of 28 million hectares. For each country, the total area of expansion due to commodity expansion was also indicated, which is about 67 million hectares. In absolute terms, land use area expansion was greatest for livestock grazing and for soy development. In relative terms area expansion (as a proportion of total land area) was greatest for soy, palm oil, and coffee in Vietnam. One may also look at the occupation by the

Table 5
Grouped within Distinct Types of Production Regions: Established, Expansion Frontier, or All Areas (See Methods for Definition)

	Selected Production Areas		Selected Production Areas
Soy Brazil	States	Palm oil Indonesia	Provinces
Established	Rio Grande do Sul, Paraná	Established	North Sumatra
Expansion	Mato Grosso, Goiás	Expansion	South Sumatra, Jambi, Lampung
Frontier	Tocantins, Maranhao, Piauí	Frontier	West Kalimantan
Soy Argentina	Provinces	Palm oil Malaysia	States
Established	Cordoba, Santa Fé	Established	Johor, Perak, Pahang
Expansion	Entre Rios, Chaco	Frontier	Sabah, Serawak
Frontier	Salta, Santiago del Estero		
Beef Brazil	States	Coffee Honduras	Departments
All areas	Mato Grosso do Sul, Pará, Rondonia	All areas	El Paraiso, Copán, Santa Barbara
Beef Argentina	Provinces	Coffee Vietnam	Provinces
All areas	Santa Fé, Corrientes, La Pampa	All areas	Dak Lak

selected commodities of certain types of soil or ecosystems. These data are available for Brazil. Here, it was estimated that recent soy expansion, while occupying an average of only 3% of total land area, now occupies 10% to 35% of suitable plateau lands within selected states (Kessler, Dros & de Bruin, 2006).

The growth factor (indicator B1) in most cases is higher than 0.40. Soy showed the highest growth factors (80% to 90%). Low growth factors occur in regions such as Rio Grande do Sul in Brazil and Johor in Malaysia, where soy and palm oil, respectively, have been produced for a long time (established region). The growth factors are highest in the frontier regions.

Indicator B2 shows that the remaining biodiversity (NCI) at the national level in the selected countries varies between 47% and 80%. In the selected production areas the NCI is higher than the national average in six cases (indication + and + +). These are mainly expansion or frontier regions, where expansion of the commodity at the expense of relatively undisturbed ecosystems predominates. In 18 cases NCI is lower (− and − −) in the selected production areas. This situation occurs mainly in established regions, as well as in all coffee areas in Honduras. Here, production increase of the agro-commodity occurs by intensification and expansion into areas with agricultural land use. Thus, although we expected commodity development to be concentrated in regions with intact ecosystems, reality appears to be different.

Table 6
Impacts on Biodiversity Through Expansion of the Selected Commodities

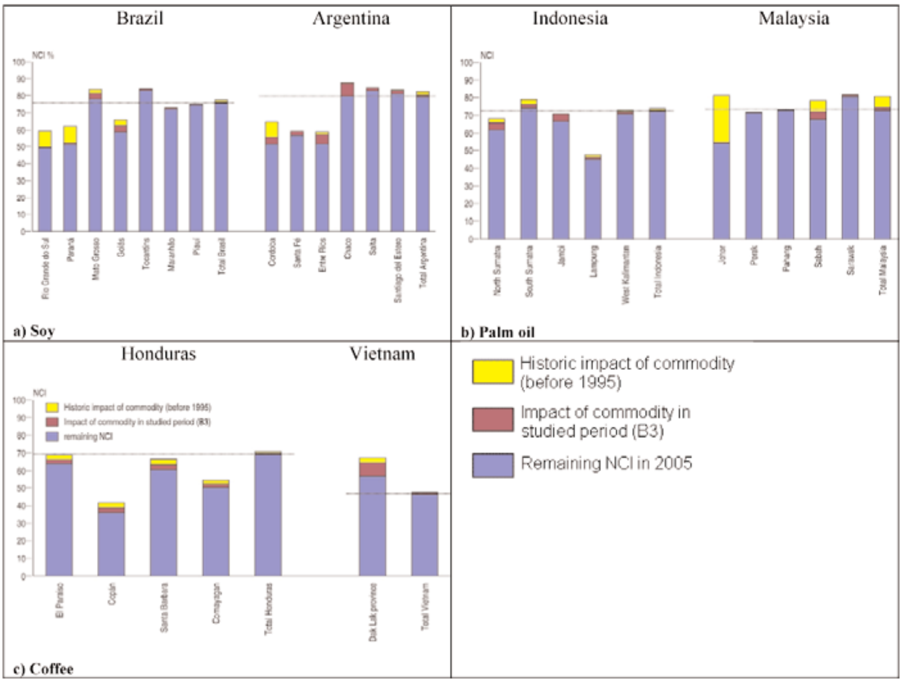
Country and Production Areas	Area Increase by Commodity (×1000 ha)	B1: Growth Factor Commodity (%)	B2: NCI in production area in 2000* (in % NCI)	B3: NCI Loss by Commodity (% NCI)	B4: Part of Commodity to NCI Loss (in %)	B5: Ecological Claim (in km^2)
Soy Brazil						
Rio Grande do Sul	962	0.24	--	1	1	1,656
Paraná	1,801	0.45	--	1	2	2,065
Mato Grosso	2,940	0.56	+	3	17	31,552
Goiás	1,470	0.55	--	4	10	13,311
Tocantins	233	0.92	+	1	5	2,407
Maranhão	253	0.74	=	1	3	2,480
Piauí	143	0.93	=	1	2	1,400
Total Brazil	9,860	0.46	76%	1	3	65,498
Soy Argentina						
Cordoba	2,500	0.60	--	4	10	7,130
Santa Fé	1,117	0.71	--	2	6	3,468
Entre Rios	988	0.87	--	6	13	4,401
Chaco	904	0.93	=	8	46	6,864
Salta	317	0.85	=	2	10	2,569
Santiago del Estero	660	0.88	=	2	10	2,743
Total Argentina	8,322	0.58	80%	1	5	30,363
Palm oil Indonesia						
North Sumatra	470	0.72	−	4	12	2,529
South Sumatra	180	0.50	=	2	8	1,112
Jambi	316	0.51	−	4	13	1,898
Lampung	60	0.55	--	1	2	270
West Kalimantan	240	0.59	=	1	4	1,615
Total Indonesia	2,300	0.52	72%	1	3	12,082

Palm oil Malaysia						
Johor	79	0.03	–	1	2	127
Perak	38	0.13	−	< 1	1	76
Pahang	80	0.15	=	< 1	2	134
Sabah	647	0.56	=	4	14	2,744
Serawak	390	0.58	+	1	6	1,237
Total Malaysia	1,600	0.41	73%	2	6	4,942
Beef Brazil						
Mato Grosso do Sul	3,700	0.12	--	5	9	17,335
Pará	6,000	0.36	+	2	20	29,129
Rondonia	2,900	0.37	+	6	36	13,580
Total Brazil	43,200	0.18	76%	2	10	198,733
Beef Argentina						
Santa Fé	450	**	--	2	6	3,328
Corrientes	500	–**	−	4	14	3,764
La Pampa	100	–**	=	< 1	2	685
Total Argentina	1,700	–**	80%	< 1	2	11,719
Coffee Honduras						
El Paraiso	21	0.47	−	2	7	252
Copán	11	0.49	--	3	4	131
Santa Barbara	18	0.47	−	3	7	209
Comayagan	13	0.48	--	2	4	165
Total Honduras	111	0.47	69%	1	3	1,001
Coffee Vietnam						
Dak Lak province	199	0.76	+ +	8	19	1,396
Total Vietnam	423	0.77	47%	1	2	2,874

* B2: classification of differences: <5%: = ; >5% and <20%: − or 1; >20%: − or + +.

** B1 could not be calculated for beef in Argentina because historical data are not available.

Figure 2
Impacts on Biodiversity (Expressed in Terms of Natural Capital Index NCI) by (a) Soy in Brazil and Argentina; (b) Palm Oil in Indonesia and Malaysia; (c) Coffee in Honduras and Vietnam. Production Areas for (a) and (b) Are Classified From Left to Right in Established, Expansion, and Frontier Regions.



We determined the multiplier effect from commodity development, which means the additional land use change as a collateral effect outside the actual cropping areas (see Methods). The highest multiplier effects occur for soy production in Brazil (87% on average) and for palm oil in Indonesia (35%). We also estimated the proportion of land occupied by the commodity being originally intact forest, or extensive or intensive cropland. In total 74% of land use change due to soy expansion in Brazil originates from natural ecosystems and 60% for palm oil in Indonesia. The other product–country combinations showed data between 30% and 35%.

Indicator B3 and Figure 2 demonstrate the biodiversity impacts of the commodity development in absolute and relative terms. The horizontal line in Figure 2 represents the NCI at the national level as a reference. The dark section of each bar reflects the NCI loss as a result of commodity expansion during the study period. The upper light section of the bar reflects the historical impact on biodiversity by the commodity development before the mid-1990s. The NCI currently remaining (2005) is the lower section. The difference between the total bar and the 100% level reflects the biodiversity loss caused by other factors.

Indicator B4 shows that in 41% of the production areas the contribution from commodity production to biodiversity loss by land use is at least 10%. These are locations where NCI was relatively high and where commodity development was important. The highest contributions to NCI loss occur for soy production in Brazil (Mato Grosso) and Argentina (Chaco), for palm oil production in Indonesia (North Sumatra, Jambi) and Malaysia (Sabah), for beef production in Brazil (Para and Rondonia) and Argentina (Corrientes), and coffee in Vietnam (Dak Lak).

Finally, indicator B5 indicates the ecological claim, and is corrected for original land use and multiplier effects. Biodiversity losses may seem to be low when expressed as percentages NCI (indicator B3). However, indicator B5 better reflects the full ecological impacts in terms of NCI being affected. For example, the 3% NCI loss caused by soy production in Mato Grosso corresponds with the loss of biodiversity in an area of 31,000 km^2. The total biodiversity loss caused by the four commodities in the selected areas within the study period corresponds to an area of 154,000 km^2, which is about four times the surface area of the Netherlands. The total ecological claim affected by these four commodities before and during the studied period and within the selected countries is 328,000 km^2.

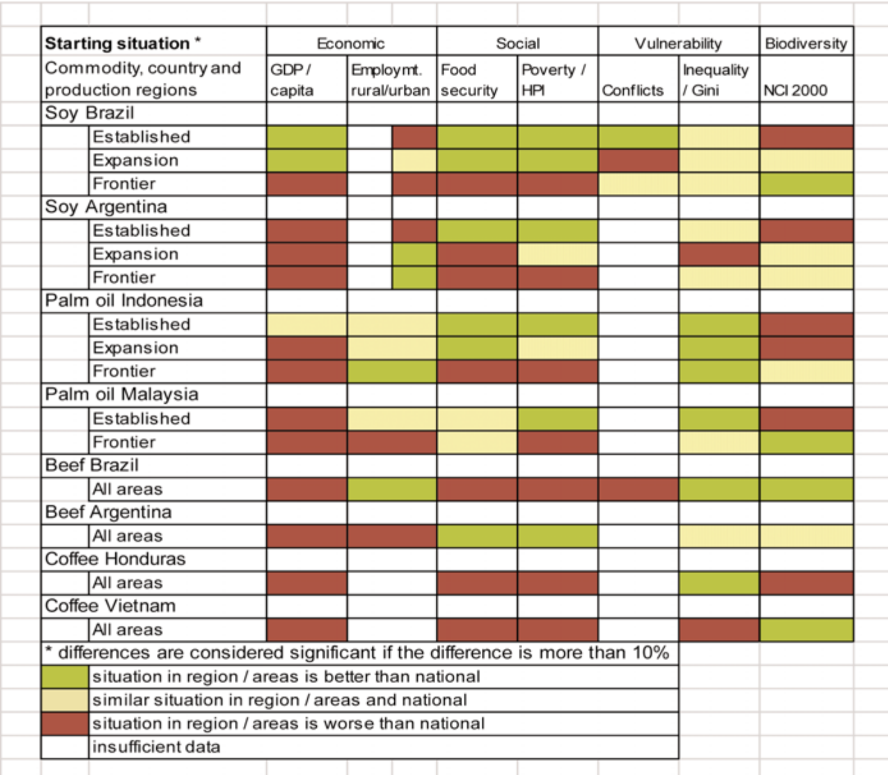
Socioeconomic Impacts

The socioeconomic indicator values generated a wealth of information, of which the analyzed results are presented. Figure 3 gives the indicator values of the starting situation, that is, the indicator values at the onset of the study period in the mid-1990s. Three different outcomes are possible: starting values in the production area are better than the national average, are similar, or are worse. The outcomes for the indicated regional categories (established, expansion, frontier, or a mix of “all areas”) represent averages for the different production areas falling within each category (see Table 5).

It appears that in 35% of the cases the starting situation in the selected production areas is better than the national average, while it is worse in 45% of cases and similar in 25%. This implies that in most cases the production areas are less developed. Better starting situations are most commonly found in production areas where the commodity has been produced for several decades (established regions). It is noteworthy that in all except three cases the GDP per capita indicator value is worse in the production areas. This underlines that the production areas are most underdeveloped in an economic sense.

Figure 4 presents the rate of change of selected indicators in the production areas during the study period as compared to the national average trends, as well as the absolute trends during the study period (with +, 0, and −). Results are based on quantitative data; only some information about conflicts is based on qualitative data.

Figure 3
Indicator Values of Key Indicators for the Starting Situation (Mid-1990s) in Selected Production Areas, as Compared to the National Average.



It appears that in almost 60% of the cases there is a positive development trend. However, only in 30% of the cases is the rate of change in the selected production areas favorable, meaning that the trend is more positive (or less negative) than the national average trend. This means that only in 30% of the cases did the selected production area fare better than what one would expect based on the national average trends. In 55% of the cases the selected production areas actually show an unfavorable rate of change (and 15% show a comparable rate of change).

Figure 5 shows the combination of the results on starting situation, trends, and rate of change, organized by four socioeconomic change patterns (see Table 3). We grouped the interpretations of "better" and "similar" for both the starting situation and the rate of change, in order to focus the analysis upon testing the main hypothesis of this study.

Figure 4
Trends and Rates of Change During the Study Period (Mid-1990s to Early 2000s) Trend Has Caused a Shift of Starting Situation From Better to Worse.

Changes recent 10 years*	Economic		Social		Vulnerability		Biodiversity
Commodity, country and production regions	GDP / capita	Employmt. rural/urban	Food security	Poverty / HPI	Conflicts	Inequality / Gini	NCI change
Soy Brazil							
Established	-	- / +	+	+	0	+	-
Expansion	-!	- / +	+	+	+	+	-
Frontier	-	- / +		+	-!	+	-
Soy Argentina							
Established	+	- / -	+	-		-	-
Expansion	+	- / -	+	-		-	-
Frontier	-	- / -	+	-		-	-
Palm oil Indonesia							
Established	+	-	+	-		-	-
Expansion	+	-	+	+		-	-
Frontier	-	-	+	-		+	-
Palm oil Malaysia							
Established	+	+	+	+		-	-
Frontier	+	+	+	+		-	-
Beef Brazil							
All areas	+	+	+	+	-	+	-
Beef Argentina							
All areas	-	-	+	+	+	+	-
Coffee Honduras							
All areas	+		+	+		+	-
Coffee Vietnam							
All areas	+		-	+	+	+	-

* differences are considered significant if the difference is more than 10%

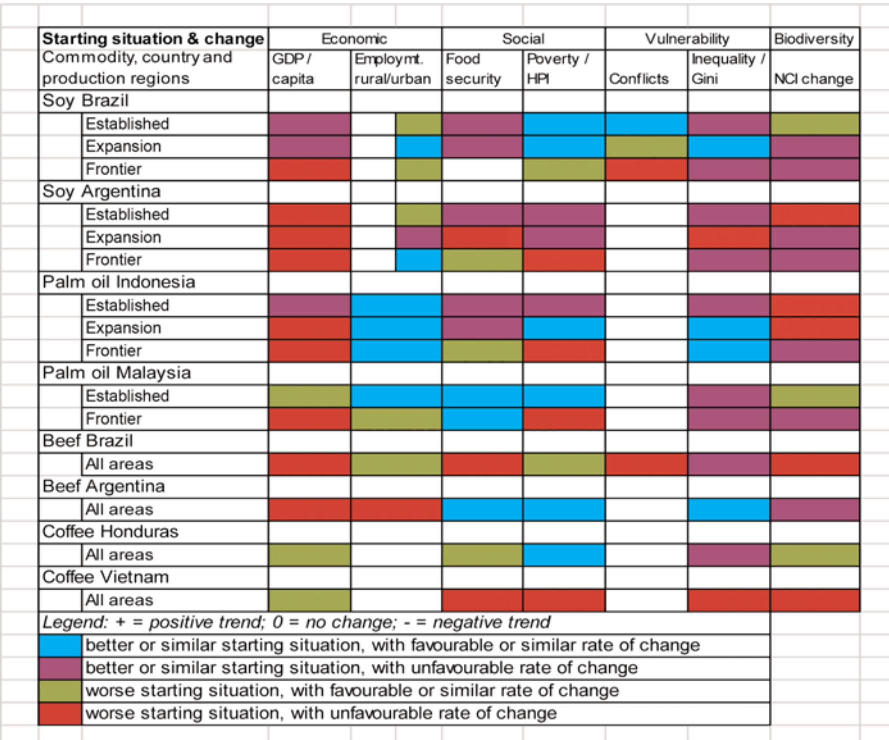
Legend: + = positive trend; 0 = no change; - = negative trend

- (green) favourable rate of change in region compared to national
- (light yellow) similar rate of change in region compared to national
- (dark red) unfavourable rate of change in region compared to national
- ! trend has caused a shift of situation from + to - or vice versa

Tables 7 and 8 show the quantitative analyses of the data. The biodiversity indications in Figures 3, 4, and 5 are the result of an interpretation of the detailed data from Table 6.

It appears that in 27% of the cases production areas with a better starting situation (i.e. better socioeconomic indicator values as compared to the national average) show further improvements, while in 19% of the cases production areas with a worse starting situation show a positive development (a “closing gap” pattern). These are positive developments. However, in 26% of the cases we find a pattern of “widening gap” in the production areas. In other words, of production areas with a worse starting position (45% of the cases), 59% will show a widening gap, in spite of (or

Figure 5
Socioeconomic Patterns (see Table 3) and NCI Changes in Selected Production Areas as Compared to National Development.



even because of) commodity development. This pattern is most prominent for the economic dimension and in particular the change in GDP per capita (Table 7), in contrast to the employment situation, which shows an improvement for some commodities, and for soy in urban areas. However, in 28% of the cases the production areas experience a “reducing advantage” pattern. In other words, of production areas with a better or similar starting situation (55% of the cases), 51% will show a widening gap due to commodity development. This pattern is most prominent for the vulnerability aspects (Table 7). Where vulnerability changes have been recorded, these were unfavorable during the study period in 67% of the cases (patterns 2 and 4), as compared to 50% and 52% for economic and social changes, respectively. High vulnerability is associated with occurrence of illegal practices, conflicts, or unequal distribution of benefits derived from agro-commodity production.

Table 7
Proportion of Socioeconomic Impacts in Four Patterns (Table 3) for Different Socioeconomic Indicator Categories (Table 2)

		Socioeconomic Impact Pattern			
Indicator category	*N*	1. Expanding Advantage (%)	2. Reducing Advantage (%)	3. Closing Gap (%)	4. Widening Gap (%)
Economic	28	21	14	28	36
GDP/capita only	15	0	20	27	53
Social	29	31	28	17	24
Vulnerability	18	28	50	5	17
Total	75	27	28	19	26

Looking at the relationship with different history and intensity of agro-commodity production (as represented by three types of regions, Table 5), we find clear insights. The pattern of "widening gap" occurs more frequently as one moves from established to expansion and frontier regions, while the pattern of "reducing advantage" shows an inverse relationship. Thus, a frontier area has a higher probability of having a worse starting situation and then is more likely to experience an unfavorable rate of change, so that the development gap widens. This is in contrast to the hypothesis being tested.

We may expect that as a result of favorable changes a worse starting situation changes towards a better situation (of the production area as compared to the national average). However, this has not happened in any case. Figure 4 shows whether such shifts have occurred. We only found the inverse to occur twice, that is, a better starting situation to change into a worse one, in both cases for soy in Brazil (GDP per capita in the expansion region changes from better to worse in the expansion region, and conflicts in the frontier region changed from similar to worse). The fact that a worse starting situation has never changed into a better (or similar) situation means that positive trends and favorable rates of change, if apparent, have not been strong enough to cause production areas with a poor development situation to fully catch up with national development levels.

A relationship between the starting situation and the rate of change of the socioeconomic indicators was not found. In other words, the socioeconomic starting situation has no influence on whether the production area will show a positive rate of change. We do observe that a favorable rate of change is in most cases associated with a positive trend direction of the indicator (Figure 4). Of the cases with a favorable rate of change, 86% has a positive indicator trend, while of the unfavorable rates of change only 50% has a positive indicator trend. By far the most negative trends (72%) are associated with unfavorable rates of change. This suggests that the national economic development context partly determines whether the commodity production process will lead to significant socioeconomic benefits in the production areas.

Table 8
Proportion of Socioeconomic Impacts in Four Patterns (Table 3) for Different Types of Production Regions (Table 5)

		Socioeconomic Impact Pattern			
Production Regions	*N*	1. Expanding Advantage (%)	2. Reducing Advantage (%)	3. Closing Gap (%)	4. Widening Gap (%)
Established	21	29	52	14	5
Expansion	16	38	31	6	25
Frontier	20	20	15	25	40
Total	57	29	19	16	23

Detailed Accounts of Cases

We will now give a more detailed description of three commodity–country combinations, for a better understanding of the integrated views that appear from the data.

For soy in Brazil, three different soy production regions were distinguished: the “established” region, a well-developed production region where soy has been produced for more than 20 years; the “expansion” region, where soy production started in the early 1990s; and the “frontier” region, where soy production started in the mid-1990s. During the study period, soy expansion in absolute figures was particularly important in the expansion region, but the relative increase was most important in the frontier region, where conditions for growing soy are less suitable and less land is available for expansion. In the frontier region, the social and economic starting situation was worse in most respects, in contrast to the other two regions, except for the incidence of conflicts, which is highest in the expansion region. Biodiversity, however, is more intact in the frontier region, as also in Mato Grosso in the expansion region, but in contrast to the established region where biodiversity is low.

During the study period, most indicator trends in Brazil were positive, with the exception of GDP per capita (expressed in U.S. dollars) due to inflation. However, all production regions show a relative decline of GDP per capita as compared to the national average, even Mato Grosso where soy has expanded most strongly. There are also negative changes in terms of rural employment and food security, but positive changes for urban employment. In the frontier region poverty is reduced more rapidly than the national average, but the poverty index in this region still remains far below the national average (positive rate of change but no shift of the situation). The GINI Inequality Index in the soy production regions is similar to the national average but the situation deteriorates in two regions (and even shifts to worse in the frontier region). High vulnerability in all production areas is associated with incidences of forced labor conditions (slavery), land conflicts and loss of autonomy during early phases of land clearing, and displacement of original land users. Conflicts particularly increase in the frontier region, while it seems that the expansion region (where the situation in the mid-1990s was particularly bad) shows an improvement. The NCI changes are negative and in both the expansion and frontier regions are worse than the average in Brazil, particularly in Mato Grosso where the NCI was still relatively high.

The pattern of beef production in Brazil is best compared with the frontier region for soy production. Beef production in Parà and Rondonia has major impacts on the loss of biodiversity (Table 6). Deteriorating vulnerability is associated with unequal land ownership: more than two-thirds of livestock herds are owned by less than 10% of the cattle farms. In the beef production areas the poverty situation is improving but food security is declining.

Both in Honduras and Vietnam the starting situations of coffee production areas are generally worse than the national average. However, whereas in Honduras most developments are positive, the opposite is true for Vietnam. This may be explained by the fact that coffee production in Honduras is well established, with a high-quality niche market, so that producers have not suffered from declining world market coffee prices. Coffee expansion and, linked to this, biodiversity loss, have been limited. In Vietnam coffee has expanded greatly at the expense of forest ecosystems, thus leading to a strong NCI decline. Vietnam has suffered much from the collapse of world market coffee prices. Although the selected coffee production area in Vietnam showed positive changes in the 1990s, both poverty and food security have recently deteriorated. This shows that the coffee "boom" has not created sustainable growth and poverty reduction in the production areas.

Conclusions and Discussion

Integrated Sustainability Impacts

Based on the analyzed changes in socioeconomic and biodiversity indicator values within the selected production areas, conclusions are now drawn on the relations between these changes and the production processes of the selected agro-commodities.

Starting from an environmental point of view, there is much variation in terms of original biodiversity (NCI value) and biodiversity losses in the selected countries and production areas. Biodiversity loss was limited for coffee in Honduras, established regions for soy in Brazil, and established region for palm oil in Malaysia.

In these situations, the NCI value in 2000 was already relatively low because of intensive occupation and land use, while the socioeconomic starting situation was relatively good and expansion of the commodity was limited. However, in all other selected countries and areas important biodiversity losses occurred, especially in expansion and frontier regions where the original NCI value was relatively high while the socioeconomic starting situation was relatively poor. Total biodiversity loss expressed as the ecological claim (indicator B5) shows that in the selected areas major biodiversity losses have occurred (up to four times the area of the Netherlands). These losses are mainly associated with soy and meat in Brazil, soy in Argentina, and palm oil in Indonesia.

From a socioeconomic point of view, it appears that the increase of agro-commodity production often takes place in areas with relatively low levels of human development. During the study period, many frontier areas show the change pattern of "widening gap" while many established regions show a pattern of "reducing advantage." These unfavorable changes mainly occur for GDP per capita and for vulnerability aspects. Positive changes occur as well but are more scattered (Figure 5). Thus, a picture emerges of some production areas, especially frontier regions, having relatively high biodiversity starting values as well as losses, and in most cases showing unfavorable socioeconomic changes. However, there are also several exceptions to this overall picture.

In terms of economic changes, it may be argued that the relative value of GDP per capita in the production areas compared to national average values cannot be expected to improve if at the national level there is important economic growth. To verify this argument, we checked whether during the study period there have been, within the selected countries, major changes in the proportion of the primary sector to national-level GDP. Although in Brazil and Argentina the proportion of the primary sector to GDP increased between 1994 and 2004, there were declines in the other countries: Indonesia 10%, Vietnam 20%, Malaysia 30%, and Honduras 45% decline. Thus, especially in the latter two countries, the economic development of the country as a whole might explain why economic development in selected production areas lags behind. However, especially in these two countries, economic changes in the selected production areas have also been positive. Note that the occurrence of the Asian financial crisis during the study period cannot explain unfavorable changes in production areas, as we looked at changes of the production areas as compared to the national average trend.

There are other arguments that point at differences between countries rather than commodities. In order to further investigate country-related factors, we looked at two macro-level indicators: the Human Development Index (HDI) rank (highest/poorest rank is 177) and the Transparency International Corruption Perceptions Index rank (TICP) (highest/poorest rank is 145).

Table 9 shows that the corruption index may help explain poor performance in Argentina and Indonesia (high scores for both countries). Brazil and Malaysia, on

Table 9
National-Level Indices for Human Development and Corruption

Country	HDI rank 2003	TICP rank 2003
Argentina	34	108
Brazil	65	59
Honduras	115	114
Indonesia	112	133
Malaysia	59	39
Vietnam	109	102

the contrary, have relatively good corruption ranks, which may explain better performance. However, in both countries, this does not exclude unfavorable changes in frontier regions mainly. Honduras scores poorly on both HDI and the corruption index, which is not in line with the above reasoning.

Conclusions on the Hypothesis

The main hypothesis of this study is that loss of biodiversity for export-oriented agro-commodity production contributes to economic growth, improved social welfare, and poverty reduction in production areas, which would support the view that trade stimulates development. Thus, one expects in particular the change patterns of "closing gap" and "increasing advantage." It should be concluded, however, that biodiversity loss for the benefit of agro-commodity production in 54% of the cases does not generate positive development (as compared to national average trends), while in 59% of cases with a poor starting situation the changes are negative, so that the development gap widens. These dynamics are in contrast with the assumption of trade stimulating development and poverty reduction. Note that the starting situation of a production area is not a factor explaining the socioeconomic change pattern.

From the analysis and insights, it appears that the observed patterns can be related to three different variables:

1. Differences between agro-commodities, some causing more biodiversity loss (e.g. biodiversity loss due to forest conversion is large for large-scale production systems of soy and palm oil) than others (e.g. coffee); some generating more rural employment (e.g. palm oil) than others (e.g. mechanized soy production).
2. Differences between countries: there is a relationship between the national development trend and the probability of a production area benefiting from the agro-commodity production process; the governance context is another possible explaining factor.
3. Differences between production regions (historical context and intensity of production systems): frontier regions are subject to the recent introduction and

expansion of the agro-commodity and show more cases of "widening gap" than established regions, while expansion regions take an intermediate position.

It is very likely that the observed changes can be attributed to the agro-commodity development, given the selection criteria of the production areas (high economic importance and rapid growth of the selected commodities), as well as the insights in the underlying dynamics (see for instance the detailed accounts of three cases). One may question whether socioeconomic changes without agro-commodity development would have been worse or better. In other words: if we have a change pattern of "widening gap," does this occur in spite of or as a result of agro-commodity development? This question cannot be answered with certainty because we have no control areas (see Methods for explanation). Although some established regions seem to benefit from agro-commodity production, some frontier regions, given the poor conditions and recent changes, do not seem to benefit at all. The fact that established regions often fare better (within or just before the study period), suggests that expansion or frontier regions will catch up in due time. However, this assumption must be questioned, as areas more recently occupied under pressure of global market demands may have fewer comparative advantages and generate fewer benefits. Most importantly, vulnerability (conflicts and inequality) always deteriorates in newly exploited areas, due to high incidence of illegal land grabbing and violence. Vulnerability is an important aspect of poverty, and suggests that, at least initially, part of the population does not benefit from the production process. Moreover, poor communities in production areas are particularly affected by the combination of unfavorable socioeconomic changes and biodiversity loss, as they are generally more dependent on ecosystem goods and services for food security and as a safety net (DFID, EC, UNDP, & World Bank, 2002; UNCTAD, 2002). Ecosystem changes will also take much time to regenerate.

Even if socioeconomic development was positive during the agro-commodity production boom, this may not be sustainable change. In Vietnam the expansion of coffee was concentrated in one poorly developed region. Although the region benefited economically during the coffee boom in the 1990s, recent data show a widening gap (as compared to national averages) in terms of food security, poverty, and inequality. This suggests that the production areas did not benefit sufficiently from the period of high revenues, and development remains dependent on incomes from resource exploitation at the expense of natural capital.

The underlying causes for the observed patterns can be several, and vary by country. Here we cite some of the causes explaining poor performance of production areas, as have appeared from the country studies:

- The rate of change—the rapid rate of agro-commodity expansion (as associated with global trade) may surpass the capacity of law enforcement authorities to respond adequately.

- Comparative advantages of production areas—more recently occupied areas (expansion and frontier regions) may have lower land suitability and thus be less productive, whereas established regions have better production conditions and comparative advantages for trade and processing industries (e.g. located near the coast).
- The absence of value added processing industries in producing areas—this may be the case particularly in frontier areas and explain their poor performance.
- Government subsidies to alleviate poverty and improve social services—this may explain why social indicators in some countries perform better than economic ones.
- Influx of migrant workers and high levels of mechanization—this may explain why we see negative rural employment changes for soy (and possibly beef).
- Law enforcement and land rights—poor law enforcement and no respect of land titles and use rights explains the occurrence of conflicts, particularly in frontier and expansion areas.
- Degree of decentralization and local autonomy—local governments may raise their own taxes, which explains why in some countries local administrations benefit from resource exploitation (e.g. in Brazil) and use revenues for social and economic development services.
- Involvement of the private sector—although some sectors are monopolized by a limited number of international companies (soy, palm oil), this is less so for others (coffee, meat).

Applicability of the Method

Our analysis method offers new perspectives for the integrated assessment of biodiversity and socioeconomic impacts of large-scale agro-commodity production processes. For biodiversity losses, we largely succeeded in distinguishing the impact from the agro-commodity development from other possible causes. We limited our assessment to biodiversity changes caused by changes in land use (intensity), which are most important in production areas. To assess socioeconomic changes, a method was developed by which available statistics and case studies were used to quantify the socioeconomic impacts. The strength of the method is the focus on the meso level and the comparison of trends in production areas with national averages. This helps overcome disadvantages of national statistics or local case studies. The method is suitable for drawing conclusions about commodity production processes that tend to be concentrated in certain areas within countries. As compared to local surveys or case studies, the method has the advantage of reaching the meso or landscape level in which production sectors are nested in a complex mosaic structure of land use and remaining natural ecosystems dynamics, as well as socioeconomic dynamics (e.g. rural–urban dynamics).

The weakness of the method is its dependence on reliable statistical data at the meso level in producing countries. The applicability also depends on:

- The proper choice of products. Products with a diversity of processing chains are more difficult to analyze than raw material flows only, especially if processing takes place at different locations.
- The choice of countries and production areas. The selected commodity needs to have high priority for the country and/or for the production areas. This will make it difficult to apply this method in urbanized areas or areas with an important service sector.
- The possibility of using control areas. This was not possible for this study, as suitable control areas were not found, but may be possible at a lower scale level (e.g. municipalities).

It can be concluded that the selected set of indicators provided insight into sustainability impacts and their interactions, and allows use of both quantitative data and qualitative information. The number of indicators is limited but sufficient to build up a reliable view and establish comparison between countries. The emerging picture is more specific and balanced and thus meets some of the criticism of the ecological footprint method.

Policy Implications

This study provides evidence casting doubts on the neoliberal assumption that agro-commodity production and trade will generally stimulate economic growth and reduce poverty in their production areas (see the Introduction). This study demonstrates that production areas may lose biodiversity (natural capital) and at the same time be subjected to processes that lead to a widening poverty gap between the production area and the national average. More research is needed to identify which factors explain these dynamics, and in particular determine the conditions for positive dynamics to occur. It can be concluded that governments and private sector agencies should be cautious in stimulating South–North trade of agro-commodities, particularly if production areas are rich in biodiversity and relatively underdeveloped. There is an urgent need to establish criteria for sustainable commodity production processes in the production countries, based on the objective to assure environmental sustainability and an equitable development path. Such initiatives do occur (e.g. round tables on sustainable palm oil and on responsible soy) but need to be supported by private sector and by government policies to become effective in the short term.

References

Alkemade, R., Bakkenes, M., Bobbink, R., Miles, L., Nellemann, C., Simons, H. & Tekelenburg, T. (2006). GLOBIO 3: Framework for the assessment of global terrestrial biodiversity. In *MNP (2006) Integrated modelling of global environmental change. An overview of IMAGE 2.4* (pp. 171–186). Bilthoven, The Netherlands: Netherlands Environmental Assessment Agency (MNP).

Atkinson, G. & Pearce, D. W. (1993). Measuring sustainable development. *The Globe*, Issue no. 13. Swindon: U.K. Global Environmental Research Office.

Brundtland Commission. (1987). *Our common future*. New York: World Commission on Environment and Development, Oxford University Press, and United Nations.

de Vries, B. & Goudsblom, J. (2002). *Mappae Mundi*. Amsterdam: Amsterdam University Press.

DFID (Department for International Development), EC (European Community), UNDP (United Nations Development Programme), & World Bank. (2002). *Linking poverty reduction and environmental management: Policy challenges and opportunities*. London: DFID.

Faaij, A. P. C., Minnesma, M. & Wiesczorek, A. J. (2003). *International debate on international bio-energy trade.* Amsterdam: Institute for Environmental Studies.

Giljum, S. & Eisenmenger, N. (2004). North–South trade and distribution of environmental goods and burdens: A biophysical perspective. *Journal of Environment and Development*, *13*(1), 73–100.

Hopfenberg, R. & Pimentel, D. (2001). Human population numbers as a function of food supply. *Environment, Development and Sustainability*, *3*, 1–15.

Kessler, J. J., Dros, J. M. & de Bruin, I. (2005). *Analyse van sociaal – economische impacts in het buitenland van Nederlandse consumptie*. Bilthoven: Netherlands Environmental Assessment Agency and Amsterdam: AIDEnvironment.

Kessler, J. J., Dros, J. M. & de Bruin, I. (2006). *Ecosystem human development dynamics in soy bean production in the Brazilian cerrado ecosystem.* Bilthoven: Netherlands Environmental Assessment Agency and Amsterdam: AIDEnvironment.

Majer, J. D. & Beeston, G. (1996). The biodiversity integrity index: An illustration using ants in Western Australia. *Conservation Biology*, *10*, 65–73.

McKinney, M. L. & Lockwood, J. L. (1999). Biotic homogenisation: A few winners replacing many losers in the next mass extinction. *Trends in Ecology and Evolution*, *14*, 450–453.

Meadows, D. H., Meadows, D. L., Randers, J. & Behrens, W. W. (1972). The limits to growth: A report for The Club of Rome's project on the Predicament of Mankind. New York: Earth Island, Universe Books.

MNP (Netherlands Environmental Assessment Agency). (2006). *Cross-roads of Planet Earth's life: Exploring means to meet the 2010 biodiversity target, Study performed for the Global Biodiversity Outlook 2*. Bilthoven, The Netherlands: Netherlands Environmental Assessment Agency.

Opschoor, H. (2000). The ecological footprint: Measuring rod or metaphor? *Ecological Economics*, *32*, 363–365.

Pearce, D. (1993). *World without end: Economics, environment, and sustainable development.* New York: Oxford University Press.

Potting, J. & Bakkes, J. (Eds.). (2004). *The GEO-3 scenarios 2002–2032: Quantification and analysis of environmental impacts.* Nairobi: United Nations Environment Programme and Bilthoven, The Netherlands: National Institute of Public Health and the Environment.

Reidsma, P., Tekelenburg, T., Van den Berg, M. & Alkemade, R. (2006). Impacts of land-use change on biodiversity: An assessment of agricultural biodiversity in the European Union. *Agriculture, Ecosystems and Environment*, *114*(1), 86–102.

Rood, G. A. & Alkemade, R. (2005). The influence of the Dutch on global biodiversity: Effects of so-called sustainable solutions. *Environmental Journal ArenA 5* (in Dutch).

Rood, G. A., Willing, H. C., Nagelhout, D., ten Brink, B. J. E., Leewis, R. J. & Nijdam, D. S. (2004). *Tracking the influence of the Dutch on global biodiversity.* National Institute of Public Health and the Environment (RIVM) Report 500013005/2004. Bilthoven, The Netherlands: National Institute of Public Health and the Environment (in Dutch).

Scholes, R. J. & Biggs, R. (2005). A biodiversity intactness index. *Nature*, 434, 45–49.

Ten Brink, B. (2000). *Biodiversity indicators for the OECD Environmental Outlook and Strategy, feasibility study.* Global Dynamics and Sustainable Development Programme, National Institute of

Public Health and the Environment (RIVM) Report 402001014. Bilthoven, The Netherlands: National Institute of Public Health and the Environment.

Transparency International Corruption Perceptions (TICP) Index. (2004). Retrieved at http://www.transparency.org/cpi/2004/cpi2004.en.html#cpi2004; last viewed August 2006.

UNCTAD (United Nations Conference on Trade and Development). (2002). *The least developed countries report 2002. Escaping the poverty trap*. Geneva: UNCTAD.

UNCTAD (United Nations Conference on Trade and Development). (2004). *The least developed countries report 2004.* Geneva: UNCTAD.

UNEP (United Nations Environment Programme). (1999). *Trade liberalisation and the environment: Lessons learned from Bangladesh, Chile, India, Philippines, Romania and Uganda.* New York: UNEP.

UNEP (United Nations Environment Programme). (2002). *Global Environment Outlook 3*. London: Earthscan Publications.

UNEP (United Nations Environment Programme). (2004). *Indicators for assessing progress towards, and communicating, the 2010 target at the global level.* UNEP//CBD/SBSTTA/10/9. Montreal: UNEP.

UNEP (United Nations Environment Programme). 2005. *Integrated assessment of the impact of trade liberalization on the rice sector.* UNEP country projects round III. A synthesis report. Geneva: UNEP/ETB.

van den Bergh, J. C. J. M. & Verbruggen, H. (1999). Spatial sustainability, trade and indicators: An evaluation of the ecological footprint. *Ecological Economics 29*, 61–72.

Van Vuuren, D. P. & Bouwman, L. F. (2005). Exploring past and future changes in the ecological footprint for world regions. *Ecological Economics,52*, 43–62.

Wackernagel, M. & Rees, W. (1996). *Our ecological footprint.* Philadelphia: New Society Publishers.

Wackernagel, M., Linares, A. C. Deurnling, D., Sánchez, M. A. V., Falfán, I. S. L. & Loh, J. (2000). *Ecological footprints and ecological capacities of 152 nations* (the 1996 Update). Oakland, CA: Redefining Progress.

Yandle, B., Bhattarai, M. & Vijayaraghaven, M. (2004). *Environmental Kuznets curves: A review of findings, methods, and policy implications.* PERC Research Studies RS-02-1a. Bozeman, MT: PERC.

Jan Joost Kessler is an ecologist who did his PhD on environmental planning and has been working in several developing countries. He now works with the foundation AIDEnvironment (Amsterdam) as a researcher on themes related to sustainable development strategies, biodiversity impact assessment, and integrated assessment of trade policies. He was responsible for conducting the study that led to this article.

Trudy Rood works with the Netherlands Environmental Assessment Agency (MNP) in Bilthoven, on the National Policy Assessment and Sustainability Team. She was responsible for a recent study on the impact of Dutch consumption on global biodiversity, and is now mostly involved in developing the Dutch sustainability balance. She was responsible for supervising the study that led to this article.

Tonnie Tekelenburg is an agro-ecologist who did his PhD on agricultural systems in Bolivia. He now works with the Netherlands Environmental Assessment Agency (MNP) in Bilthoven, on the Nature, Landscape and Biodiversity Team. He is heading a program on international biodiversity that looks specifically at the relations between biodiversity and poverty in developing countries. He was responsible for the biodiversity assessment as part of this study.

Michel Bakkenes works with the Netherlands Environmental Assessment Agency (MNP) in Bilthoven, on the Nature, Landscape and Biodiversity Team. He has been involved intensively in developing the GLOBIO (global biodiversity) model that has been used, among others, for preparing the UNEP Global Environment Outlook IV. He was responsible for the natural capital index calculations in this study.