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Research, part of a Special Feature on Scale and Governance

The Role of Governance in Agricultural Expansion and Intensification: a Global Study of Arable Agriculture

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ABSTRACT. In this research we studied empirical relationships between agricultural production dynamics and six quantitative World Bank governance indicators for 173 countries between 1975 and 2007. It is hypothesized that in countries with lower quality of governance, agricultural production increases are more likely to be achieved by area expansions than by increases in yields. We distinguished four groups of countries: those with both area and yield increases; those with increasing yields but decreasing area; those with decreasing yields but a growing area; and those with both declines in yields and area. We analyzed differences between these four groups, and also analyzed governance-production relationships within these groups. On average, quality of governance is low in countries with both area and yield increases and high in countries with increasing yields but decreasing area. Countries with declining yields were too few in number to allow for quantitative analyses. The analysis of governance-production relationships within the four groups suggests that countries with a lower quality of governance are more inclined to achieve production increases by expanding agricultural area rather than increasing yields. Additional explanatory value of governance indicators to agricultural production dynamics is generally small, but nevertheless significant in most cases. Our results suggest that, in order for agricultural production to increase without excessive expansions of agricultural area, governance issues should be resolved.

Key Words: *cropland; development; empirical; farming; governance; intensification*

INTRODUCTION

Recently, the Food and Agriculture Organization (FAO) adjusted its projections of future food and feed demand (FAO 2009*a*). Because of population growth and, more importantly, a rise in economic welfare, global food and feed production should increase by 70% by 2050. To attain such an increase in production, cultivated area has to expand and/or yields have to increase. Although some argue that there is a vast potential for yield increase to meet the required production increase (Neumann et al. 2010), the question remains whether or not this increase in yields is likely to happen. The potential for yield increase is highest in developing countries, where current productivity levels are far below potentially attainable levels (Byerlee and Fischer 2002, Marra et al. 2003). However, many developing countries are also characterized by a lower quality of governance, which may hinder yield increase for a number of reasons. One is that investments in research and development are too low to achieve the region-specific technology required for yield increase; second is that the investment climate at farm level is often unfavorable so that buying equipment and inputs required for intensification is difficult; and third, natural areas are abundant and not well protected, making expansion of agricultural area at the expense of nature an attractive alternative to intensification (Kakonge 1998).

In the past, many attempts have been made to describe and predict agricultural yields and land use at a global level. Most of the studies concerning yields had a biophysical character (Soltani et al. 1999, Harrison et al. 2000, Hafner 2003, Nuemann et al. 2010), whereas most of the land use studies had an economic character (Veldkamp and Fresco 1996, Rounsevell et al. 2005, Eickhout et al. 2006, Mittenzwei et al. 2007). Although numerous examples of cases where rural conditions were affected by governance can be found in literature, quantitative, global analyses of governance effects

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on agriculture are few. Those that sketch effects of policies are relatively abundant (EC 2000, Van Kersbergen and Van Waarden 2004, Biermann 2007, Jansson et al. 2008), but those that relate overall governance quality to agriculture are rare. Only recently has more attention been paid to governance effects (IFPRI 2006, von Braun and Islam 2008, FAO 2009*b*, FAO 2009*c*) on agriculture. These qualitative studies related governance regarding land transactions, i.e., access to market and property rights enforcement, to investments in research and development, i.e., yield increase. However, they did not demonstrate that governance characteristics are indeed significant factors for aggregate agricultural production. In general it can be said that governance studies were mostly characterized by qualitative studies of one single regime, which could hardly be used to make global quantitative inferences (Cash et al. 2006). Now that the World Bank made a global inventory of governance indicators, we can identify the role of governance in agricultural dynamics.

To examine whether or not governance characteristics are indeed significant factors determining production increases, and whether these are obtained from yield increase or from area expansion, an empirical analysis of historical tendencies of yield increase and area expansion was performed. These observed agricultural production dynamics, i.e., changes in cultivated arable area and crop yields, were related to six governance indicators that were recently produced by the World Bank (Kaufmann et al. 2009). Using linear regression techniques, we test the hypothesis that in countries with lower quality of governance, agricultural production increase is more likely to be achieved by area expansion than by increase in yield.

DATA

When studying real-world phenomena that are the result of complex processes by means of regression analysis, it is hardly ever possible to isolate the role of the explanatory variable of interest from a wide range of other explanatory variables. In our case, we are interested in how well governance indicators can explain agricultural production indicators, but we cannot escape from the fact that governance is correlated to many other variables that also explain production indicators, e.g., climate, soils, economy, and demography. For this reason, we try to include these other variables as much as possible to account for their potential impact. We will refer to these variables as control indicators. Because of statistical confounding we will not be able to distinguish exactly which part of the explanatory power of the regression can be attributed to each of the two categories, i.e., the governance indicators and the control indicators. We can nevertheless measure a range of the explanatory power of governance. The upper limit of this range is provided by the explanatory power of the governance indicators only, and the lower limit is provided by the explanatory power of the governance indicators in addition to the explanatory power of the control indicators. The upper limit is likely to overestimate explanatory power of governance, because this estimate assumes that all common explanatory power of the two categories of indicators should be attributed to the governance indicators only. Conversely, the latter one is likely to underestimate explanatory power of governance, because this estimate assumes that all common explanatory power of the two categories of indicators should be attributed to the control indicators. Therefore, true explanatory power of governance is likely to be within this range (Bakker et al. 2005).

Because all indicators had to be measured in a similar manner for all countries in the analysis, we were limited to use global databases such as those of the FAO and the World Bank. Countries for which no consistent data existed because they either merged or split up into separate states during the study period (1975-2007), e.g., former USSR, former Socialist Federal Republic of Yugoslavia, Czech Republic, Slovakia, and Ethiopia, were not included. In total, 173 countries were included in the analysis. Because we are interested in dynamics, most indicators were computed as relative changes between approximately 1975 and 2007. Only for those indicators that were considered static in time, e.g., soil variables, or for which sufficiently long time series were not available (governance), a state variable was used. For most of the control indicators, both a change and an initial state value were used. Changes were computed as the ratio between initial states and final states. To correct for interannual variability, initial states were computed as the average over the period 1975-1980 and final states were computed as the average over 2002-2007. All dependence on country size and population size was eliminated by working with relative values, e.g., changes relative to the initial value or densities or fractions.

Production indicators

Production dynamics between 1975 and 2007 were expressed in terms of change in production, change in yield, and change in cultivated area, all between 1975 and 2007 (Table 1). Clearly, one of these three indicators is superfluous, i.e., given any two of these, the third can be calculated. For this reason, we only use changes in yield and cultivated area. However, the mathematical relationship that describes how these latter two indicators contribute to production change provides insight that is important for interpretation. Therefore, production change is also described in the derivation below, although it is not used in the analyses.

Yield changes were calculated for all different crop types recorded in the FAO database (http://faostat.fao.org/site/567/default.aspx#ancor), after which a weighted average was calculated on the basis of the average cultivated area per crop type:

$$dY \equiv Log\left[\frac{\sum_i \left(\frac{A_i Y_{1,i}}{Y_{0,i}}\right)}{\sum_i A_i}\right] \approx Log\left[\frac{Y_1}{Y_0}\right] \quad (1)$$

To account for interannual yield variability, $Y_{1,i}$ is the average yield over 2002-2007, for crop *i*, and $Y_{0,i}$ is the average yield over 1975-1980, for crop *i*. A_i is the average cultivated area for crop *i* over 1975-2007. By computing yield changes separately for all individual crops before averaging, effects of shifts from heavy crops, e.g., potatoes, to light crops, e.g., fibers, or from crops undergoing strong yield increase to crops undergoing small yield increase, are not mistaken for yield changes. All changes were expressed as the log of the ratios of these averaged initial and final values, to rescale the skewed distribution and nonequidistant data, resulting from working with positive ratios and strongly varying growths/declines. This expression (Eq. 1) is defined as *dY* and approximates the yield change at national level (Y_1 divided by Y_0).

Similarly, changes in cultivated area were also calculated for all of the recorded crop types:

$$dA \equiv Log\left[\frac{\sum_i A_{1,i}}{\sum_i A_{0,i}}\right] = Log\left[\frac{A_1}{A_0}\right] \quad (2)$$

in which $A_{1,i}$ is the average cultivated area over 2002-2007, for crop *i*, and $A_{0,i}$ is the average cultivated area over 1975-1980, for crop *i*. This expression is defined as *dA* and approximates the change in total cultivated area at national level (A_1 divided by A_0).

By calculating change in this way, one creates dimensionless quantities providing information on change between the first and last five years, standardized for country-dependent properties such as size. Adding the left and right hand sides of Eq. 1 and Eq. 2, we obtain an approximation of the change in total production at national level, defined as *dP*:

$$dY + dA = Log\left[\frac{Y_1}{Y_0}\right] + Log\left[\frac{A_1}{A_0}\right] \approx Log\left[\frac{P_1}{P_0}\right] \equiv dP \quad (3)$$

Therefore, *dY* can be interpreted as the relative contribution of a change in yield to *dP*, thus reflecting a trend toward more intensive ($dY > 0$) or toward less intensive ($dY < 0$) agriculture. Similarly, *dA* can be interpreted as the relative contribution of a change in cultivated area to *dP*, thus reflecting a trend toward more extensive ($dA > 0$) or toward less extensive ($dA < 0$) agriculture.

Governance indicators

The World Bank identified six indicators for governance (Kaufmann et al. 2009):

Voice and accountability represents the extent to which citizens have political rights and civil liberties, and are able to participate in selecting their government. Yields were found to be significantly higher in countries with more political rights and

Table 1. Production, governance, and control indicators.

Indicators	Source
Production indicators	
Aggregate change in total agricultural production (-)	FAO †
Aggregate change in total cultivated area (-)	FAO †
Aggregate change in yield (-)	FAO †
Governance indicators	
Voice and accountability (index between -2.5 and 2.5)	World Bank ‡
Government effectiveness (index between -2.5 and 2.5)	World Bank ‡
Regulatory quality (index between -2.5 and 2.5)	World Bank ‡
Rule of law (index between -2.5 and 2.5)	World Bank ‡
Political stability and absence of violence/terrorism (index between -2.5 and 2.5)	World Bank ‡
Control of corruption (index between -2.5 and 2.5)	World Bank ‡
Control indicators	
Change in agricultural export value index (-)	FAO §
Initial agricultural export value index (share of total export value) (-)	FAO §
Change in agricultural import value index (-)	FAO §
Initial agricultural import value index (share of total import value) (-)	FAO §
Change in net trade flow value (export minus import) (-)	FAO §
Initial net trade flow value (export minus import) (share of total value) (-)	FAO §
Change in GDP (PPP) (-)	World Bank |
Initial GDP (PPP) (International $/capita/yr)	World Bank |
Change in economically active agricultural population (-)	FAO ¶
Initial economically active agricultural population (share of total) (-)	FAO ¶
Change in total population (-)	FAO ¶
Initial total population density (persons/Km²)	FAO ¶
Change in total economically active population (-)	FAO ¶
Initial economically active population (share of total) (-)	FAO ¶
Change in urban population (-)	FAO ¶
Initial urban population (share of total) (-)	FAO ¶
Change in rural population (-)	FAO ¶
Initial rural population (share of total) (-)	FAO ¶
Annual mean temperature (°C)	Worldclim #
Annual precipitation (mm)	Worldclim #
Fraction of area constrained by aluminum toxicity (-)	FAO ††
Fraction of area constrained by salinity (-)	FAO ††
Fraction of area constrained by high phosphorus fixation (-)	FAO ††

† FAO, faostat, accessed 01-09-09 (http://faostat.fao.org/site/567/default.aspx#ancor);
‡ World Bank, accessed 01-05-09 (http://info.worldbank.org/governance/wgi/index.asp);
§ FAO, tradestat, accessed 01-09-09 (http://faostat.fao.org/site/406/default.aspx);
| World Bank; World Development Indicators, accessed 01-05-09 (http://www.worldbank.org/data); the international dollar is a hypothetical unit of currency that has the same purchasing power that the U.S. dollar had in the United States at a given point in time, in this case the year 2000.
¶ FAO, popstat, accessed 01-09-09 (http://faostat.fao.org/site/452/default.aspx);
# Worldclim, accessed 01-05-09 (http://www.worldclim.org/methods);
†† FAO, terrastat, accessed 01-09-09 (http://www.fao.org/ag/agl/agll/terrastat).

civil liberties (Fulginiti et al. 2004), indicating that agricultural development is related to voice and accountability. Agricultural development requires interactions between the rural population, e.g., labor unions and agricultural associations, and government agencies, e.g., extension service and ministry of agriculture. Such interactions are believed to benefit from political rights and civil liberties. Furthermore, governance influences agricultural policies, tax levels, and the conditions under which subsidies are granted. The extent to which the rural population can influence governance by political votes is therefore supposed to express itself in improved conditions for the rural population (Binswanger and Deininger 1997).

Government effectiveness refers to the provision, by government agencies, of public goods and services, and quality thereof, such as infrastructure and governmental agricultural research programs. Infrastructure plays a key role for the agricultural potential of remote rural areas to be used; agricultural research and development play a key role for yield increases (Thirtle et al. 2003). Therefore, whether or not these public goods and services can be delivered effectively by the government is crucial to agricultural development. Moreover, government effectiveness is known to provide an adequate measure with respect to the quality of these public goods and services, and in particular for agricultural research and development (Thirtle and Piesse 2007).

Regulatory quality expresses how well private sector development is promoted by the government. A poor promotion of private sector development may negatively affect the performance of free market mechanisms and investment climate, e.g., making it difficult for investors to get loans. In many countries, poor regulatory quality is caused by industrial protectionism: domestic trade policies disturbing the balance between domestic and world prices and preventing access to international markets, thereby obstructing private sector development (Lio and Liu 2008). Furthermore, countries with poor regulatory quality tend to implement policies that result in high taxation of agriculture, which also has negative effects on private sector development and investment (Krueger et al. 1991).

Rule of law represents quality of contract and law enforcement in general. Poor contract and law enforcement hinders the protection of property and the rights of landowners and tenants. In that case, advances in agricultural development, i.e., yield increase, are unlikely because these advances strongly depend on private investments in agricultural research and development (Thirtle et al. 2003). Such investments are not likely to be made, when investors cannot be assured of future revenues.

Political stability and absence of violence measures the public perception of the likelihood of destabilization or overthrowing of a government by unconstitutional or violent means, leading to domestic violence and terrorism. It is well known that when violent political conflicts arise in a country, food security is compromised by failure of economic and social networks (Hussain and Herens 1997). In countries facing higher levels of political conflict and war, yields were reported to be significantly lower during these periods (Fulginiti et al. 2004). Therefore, violent political destabilization or overthrowing of government would have negative effects on agriculture.

Control of corruption refers to the extent to which public power is abused for private goals and gain. In countries where corruption is controlled, impartial authorities are often provided to check for corruption of conventional authorities and to hold them accountable if necessary. This increases the likelihood that power and funds are used for what they were intended. In countries that fail to control corruption, powerful individuals have the opportunity to abuse their influence to their advantage, at the expense of other less powerful individuals, e.g., farmers. For example, it has been suggested that large fertilizer producers persuaded African governments to impose particular fertilization programs upon farmers through bribery and other forms of corruption (World Bank 2010), despite the fact that farmers often knew more about the particular deficits of their soils. Imposing these programs resulted in a loss of this knowledge, while crop yields hardly benefited from the traditional N, P, and K fertilizers that were, after all, developed in and for temperate zones.

Annual governance indicator data were available for all six indicators and all 173 countries, during 1996-2008. This period is too short to compute a meaningful relative change, and does not correspond to the period for which other indicators were available (1975-2007). Therefore, averages were calculated over 1996-2008 for all governance indicators, which were included in the regression.

Control indicators

Control indicators include biophysical, demographic, and economic indicators (Table 1). These control indicators were chosen because they are known to be important determinants of agriculture in general. Most control variables are correlated with governance for a variety of reasons. As mentioned earlier, because of this correlation we can only identify a range of likely governance impact. Because we also include control indicators that are quite closely connected to governance, particularly the economic indicators, we limit our assessment of governance importance to that aspect of governance that is independent from economic performance. Because economic indicators are generally associated with overall quality of governance, the marginal explanatory values of governance are likely to be underestimations.

METHODS

Between groups analysis

Groups of countries were classified according to their production dynamics, derived from *dY* and *dA*. Figure 1 presents a diagram of the different groups of countries according to this classification. In this diagram, countries can be in quadrant 1: area and yield increase; quadrant 2: area decrease and yield increase; quadrant 3: area and yield decrease; or in quadrant 4: area increase and yield decrease. We refer to these four groups as follows: “growth” countries with expansion of cultivated area and increasing yield (Q1); “intensifying” countries with contraction of cultivated area but increasing yield (Q2); “decline” countries with contraction of cultivated area and decreasing yield (Q3); and “expansion” countries with expansion of cultivated area but decreasing yield (Q4). To explore differences between these groups in terms of control and governance indicators, we performed an Analysis Of Variance (ANOVA). Specifically, separate T-tests were performed for all possible pairs of different quadrants and indicators, provided that the number of observations was sufficient. This analysis is referred to as the between groups analysis.

Within groups analysis

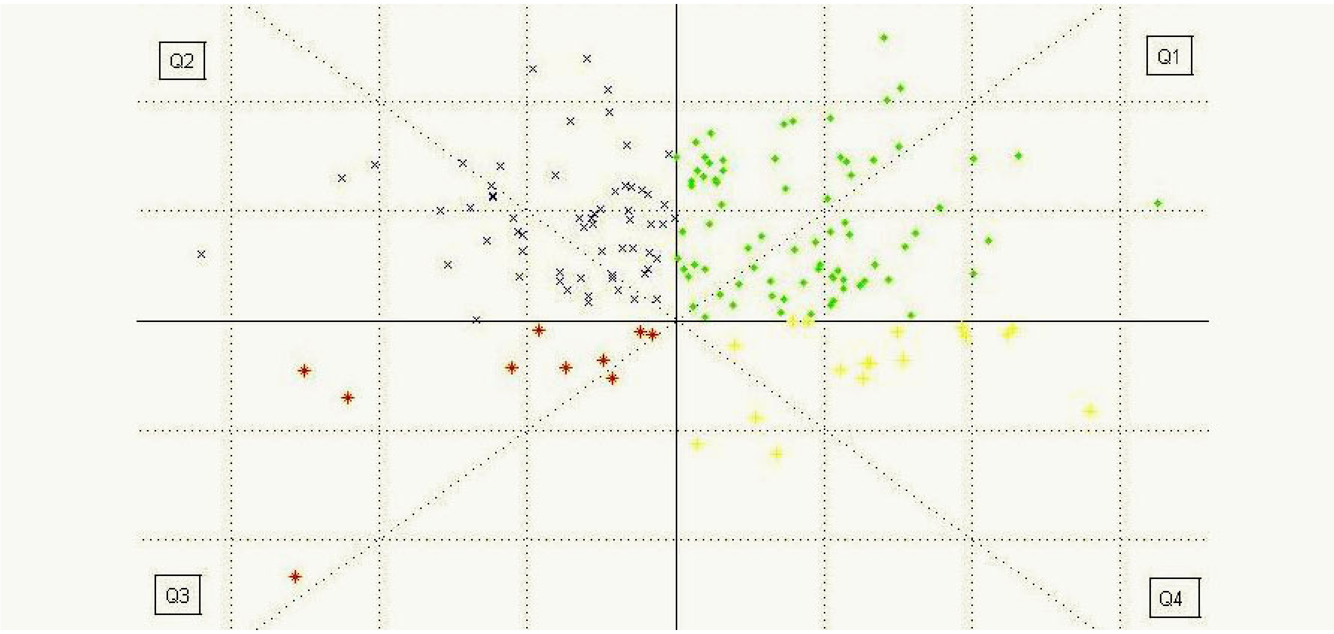
Next, to test the maximal and marginal explanatory value of governance indicators, we performed linear regressions for all countries together and for the groups individually. Although the between groups analysis distinguished countries based on the sign of *dY* and *dA*, the within groups analysis investigates the spatial variability in *dY* and *dA* values within groups, taking into account their correlation with governance and control indicators. Multivariate regression analysis was applied to examine relationships between governance indicators and *dY* and *dA*. Because the number of observations was not high enough to allow for the use of all indicators, a preselection (per group and dependent *dY* and *dA*) of indicators was made. This was done using the following criteria: only one out of two correlated indicators (i.e., with a Pearson correlation coefficient > 0.65) was kept in the selection. Furthermore, only indicators that were significant ($p \leq 0.05$) in univariate regressions (with *dY* and *dA*) were selected for further analysis. For the governance indicators, a significance level of $p \leq 0.1$ was used, because we assume that the explanatory power of governance variables is often only revealed in combination with other control indicators, i.e., statistical interaction between governance and control indicators. The maximal and marginal explanatory power of the governance indicators were identified. The maximal explanatory power was obtained by using only the governance indicators. The marginal explanatory power was obtained by comparing the model containing all governance and control indicators to a model containing only the control indicators. Furthermore, the signs of the relationships between quality of governance and area and yield change were determined. This was done by examining whether area or yield change decreased or increased when all governance indicators increased by a value of 1, i.e., those that were significant.

RESULTS

Between groups analysis

All 173 countries were classified based on changes in yield *dY* and cultivated area *dA* as shown in Figure 1. For any country in the diagram, the position relative to the origin reflects a change in production

Fig. 1. Log of relative change in yield (dY) and log of relative change in cultivated area (dA) on the y and x axis, respectively, both at national level, for 173 countries (dP ≈ dY + dA). Q1 holds "growth" countries, Q2 "intensifying" countries, Q3 "decline" countries, and Q4 "expansion" countries (see Methods: Between groups analysis).

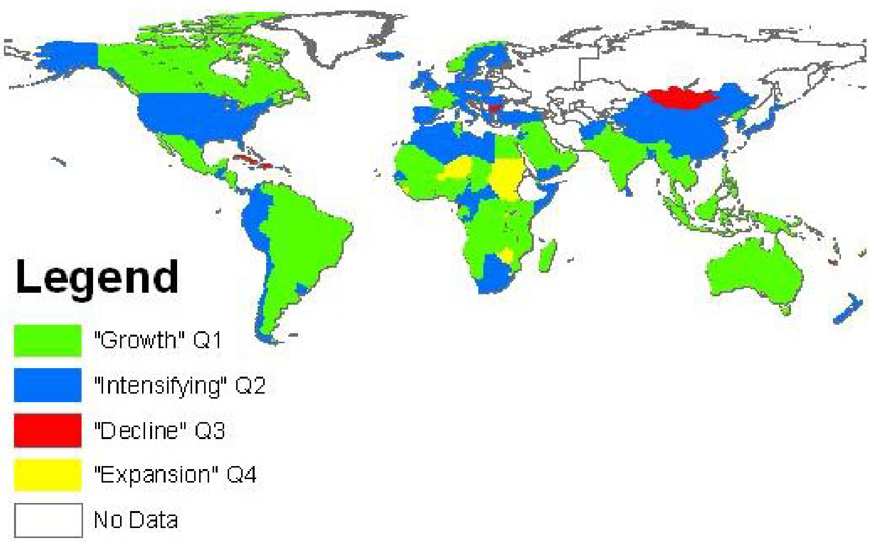


during 1975-2007, because *dP* is approximated by the sum of *dY* and *dA*. Production decreased in all countries below the diagonal with negative slope, whereas production increased in countries above it . On the diagonal, changes in area and yield offset one another; $dP \approx 0$. On the diagonal with positive slope, changes in production are not dominantly attributable to either changes in area or changes in yield; $dA = dY$. Below it, $dA > dY$, and above it, $dA < dY$.

From Figure 1 it becomes clear that countries with a yield decline are a minority. Figure 2 shows that total areas of decline and expansion countries are negligible compared with that of growth and/or intensifying countries, and that growth and intensifying countries roughly divide the area in two. Furthermore, most growth countries are developing or industrializing countries. Mexico, most of South America, most of Africa, most of the Middle East, and South East Asia, but also Canada, Australia, France, and Norway are in the growth quadrant. Canada and Australia are developed and wealthy countries in which land is abundant, and therefore a cheap resource. France and Norway negligibly increased their cultivated area and are bordering between growth and intensifying behavior. Conversely, the bulk of intensifying countries is made up by industrializing to developed countries. Most of Europe, New Zealand, the United States of America, small parts of South America: Colombia, Ecuador, Peru, Chile and Uruguay; China, Japan, Turkey, some of the wealthier African countries: Algeria, Libya, Morocco, Botswana, and South Africa; but also Afghanistan, Yemen, and the African countries of Senegal, Cameroon, Republic of the Congo, and Somalia are in the intensifying quadrant. These last few countries clearly deviate from the bulk of intensifying countries in terms of wealth and development.

Table 2 shows means and significant differences in means of the different indicators between the groups of countries. For those indicators that were not significantly different with respect to other quadrants, only the means are given.

Fig. 2. Geographical representation of the four groups of countries, depending on the signs of *dY* (log of relative change in yield at national level) and *dA* (log of relative change in cultivated area at national level).



With respect to governance, Table 2 shows that differences between growth countries and intensifying countries are most significant, and also that numbers of observations for these two groups are highest. Furthermore, expansion countries differ strongly from intensifying countries because all but one governance indicators differ significantly. On average, high quality of governance is mostly seen in intensifying countries, far above global average in general. The average quality of governance is significantly lower in the other groups. Remarkable is that decline countries distinguish themselves from other groups by their relatively high political stability. Growth and intensifying countries differ in terms of biophysical control indicators as well. Growth countries are warmer and have more severe biophysical constraints than intensifying countries. The present welfare level in intensifying countries is at ~ $20,100 per capita per year, compared with ~ $14,050 per capita per year for decline countries. The present welfare levels in growth and expansion countries are at ~ $10,700 per capita per year and ~ $2,600 per capita per year, respectively. Contrary to intensifying and decline countries, agricultural labor force strongly increased for expansion and growth countries. Finally, initial population density was almost twice as large for intensifying countries, compared with the other groups.

Within groups analysis

The within groups analysis could only be performed for the total number of countries, and for the growth and intensifying countries, because there were not sufficient observations for decline and expansion countries for reliable regressions; n = 10 and n = 18, respectively. Table 3 presents how well the variance of production indicators is explained by the biophysical, demographic, and economic control classes, separately and together, and how well it is explained by governance, maximally and marginally.

Area increases are strongly controlled by economic and demographic indicators for growth countries (Table 3). Yield increase could be less well described, but also seems to be controlled mostly by economic indicators. Governance explains between 3% and 19% of variance of change in cultivated area and between 2% and 9% of variance of change in yield. The sign of the relationship between governance and area change is negative, meaning that the higher the quality of governance, the lower the area increase. The relationship between governance and yield change is positive, meaning that the higher the quality of governance, the higher the yield increase. For intensifying

Table 2. Between groups analysis of means. Mean values of indicators per quadrant, and in parentheses the other quadrants from which means significantly differ according to T-tests. On the right, total means of these variables. $p \leq 0.1$*, $p \leq 0.05$**, $p \leq 0.01$*** Statistical software: R for statistical computing version 2.8.0 (2008).

	Growth (Q1), N = 80	Intensifying (Q2), N = 65	Decline (Q3), N = 10	Expansion (Q4), N = 18	All, N = 173
Governance indicators					
Voice and accountability	-0.25 (Q2***)	0.32 (Q1***, Q4*)	-0.02	-0.14 (Q2*)	-0.01
Government effectiveness	-0.25 (Q2***)	0.43 (Q1***, Q4***)	-0.22	-0.38 (Q2***)	-0.001
Regulatory quality	-0.26 (Q2***)	0.41 (Q1***, Q4***)	-0.11	-0.45 (Q2***)	-0.01
Rule of law	-0.23 (Q2***)	0.34 (Q1***, Q4*)	-0.26	-0.18 (Q2*)	-0.01
Political stability	-0.19 (Q2*, Q3**)	0.08 (Q1*)	0.27 (Q1**)	0.00	-0.04
Control of corruption	-0.25 (Q2***)	0.4 (Q1***, Q4**)	-0.27	-0.18 (Q2**)	0.01
Control indicators					
Economic					
Change in agricultural export value index	0.53	0.51	0.04	0.07	0.44
Initial agricultural export value index (share of total export value)	237.46	113.47 (Q4*)	175.50	286.39 (Q2*)	187.89
Change in agricultural import value index	0.77 (Q3*)	0.73	0.61 (Q1*)	0.70	0.74
Initial agricultural import value index (share of total import value)	44.50	44.08	63.48	51.41	46.38
Change in net trade flow value (export minus import)	-0.08 (Q4**)	-0.14 (Q4*)	-0.28	-0.51 (Q1**, Q2*)	-0.16
Initial net trade flow value (export minus import) (share of total value)	182.20	69.39 (Q4*)	112.02	234.97 (Q2*)	137.92
Change in GDP (PPP)	0.57 (Q2***)	0.7 (Q1***)	0.72	0.46	0.62
Initial GDP (PPP) (International $/capita/yr)	2880.80 (Q4***)	4006.30 (Q4***)	2678.10	907 (Q1***, Q2***)	3275.40
Change in economically active agricultural population	0.11 (Q2***)	-0.15 (Q1***, Q4***)	-0.10	0.16 (Q2***)	0.01
Initial economically active agricultural population (share of total)	0.51 (Q2***, Q3**)	0.32 (Q1***, Q4***)	0.36 (Q1**, Q4**)	0.55 (Q2***, Q3**)	0.43
Demographic					
Change in total population	0.32 (Q2***)	0.18 (Q1***)	0.17	0.26	0.25
Initial total population density (persons/ Km2)	79 (Q2*)	176 (Q1*, Q3*, Q4*)	80 (Q2*)	82 (Q2*)	116
Change in total economically active population	0.33 (Q2***)	0.21 (Q1***, Q4*)	0.22	0.28 (Q2*)	0.27
Initial economically active population (share of total)	0.39 (Q4**)	0.40 (Q4**)	0.38	0.36 (Q1**, Q2**)	0.39

(con'd)

Change in urban population	0.19 (Q2***, Q3***)	0.11 (Q1***)	0.07 (Q1***, Q4***)	0.23 (Q3***)	0.16
Initial urban population (share of total)	0.39 (Q2***)	0.54 (Q1***, Q4***)	0.47 (Q4*)	0.32 (Q2***, Q3*)	0.44
Change in rural population	-0.17 (Q3*)	-0.16	-0.10 (Q1*)	-0.14	-0.16
Initial rural population (share of total)	0.61 (Q2***)	0.46 (Q1***, Q4***)	0.53 (Q4*)	0.68 (Q2***, Q3*)	0.56
Biophysical					
Annual mean temperature (°C)	22.80 (Q2***)	17.60 (Q1***, Q4***)	20.40	24.10 (Q2***)	20.80
Annual precipitation (mm)	1361.60	1140.00	1475.70	1273.50	1274.20
Fraction of area constrained by aluminum toxicity	22.30 (Q2**)	14.60 (Q1**)	25.50	19.90	19.20
Fraction of area constrained by salinity	4.20 (Q2**)	1.70 (Q1**)	3	1.30	3
Fraction of area constrained by high phosphorus fixation	6 (Q2***)	2 (Q1***)	9.20	6.40	4.50

countries, economic indicators appear to be important determinants as well. It is striking that biophysical constraints do not seem to play a role for these countries. Governance explains between 0% and 8% of variance of area decrease and between 7% and 22% of variance of yield increase. For yield increase, the maximal governance class gives a lower value of explained variance than the marginal governance class, which points to interactions between the governance and control indicators. The sign of the relationship between governance and area decrease is again negative, indicating that better governance is associated to stronger area decreases. The sign of the relationship between governance and yield increase is again positive. Clearly, the bandwidth of variance explained by governance is higher for area increase for growth countries, and higher for yield increase for intensifying countries, roughly in opposite magnitudes.

For all groups combined, economic factors explain a significant part of the global variance in changes in area and yield. Area changes are also determined by demographic and biophysical constraints. Governance explains between 4% and 7% of variance of change in cultivated area and between 2% and 9% of variance of change in yield, similar to results found by others (Kok and Veldkamp 2001). The bandwidths of variance explained by governance are now in the same range of magnitude. The signs of the relationships are again negative for area change, and positive for yield change.

DISCUSSION

The results from the two analyses presented here confirm the hypothesis that in countries with lower quality of governance, agricultural production increase is more likely to be achieved by area expansion than by increase in yield. Although governance indicators do not explain vast shares of spatial variability in cultivated area and yield change within groups, a nonzero marginal explanatory value considerably increases the likelihood that governance does matter. In reality, the strengths of relationships are likely to be somewhere in between the most strictly (marginal R^2) and loosely held criteria (maximal R^2). Overall, the chosen set of control indicators seems adequate in explaining spatial variability in production indicators other than governance indicators, because of the overall consistency of results. Evidently, control and governance indicators can never be entirely separated, and interaction is likely to be present in the real world, e.g., countries with poor governance suffering more from a harsh climate than countries with a similar climate but good governance. In the case of yield change in intensifying countries, interaction is even such that marginal explanatory power exceeds maximal explanatory power.

From Table 2 we could tell that quality of governance in growth countries differs most from that in intensifying countries, and that expansion countries also differ strongly from intensifying

Table 3. Variance explained (R2) by classes and combinations of classes, per quadrant and dependent. *dY* is the log of relative change in yield at national level, and *dA* the log of relative change in cultivated area at national level. N.S. = Not Significant. Sign of relationship refers to whether *dA* or *dY* decreases (negative) or increases (positive), upon increasing the quality of governance in the maximal governance class regression equations. Statistical software: R for statistical computing version 2.8.0 (2008).

	Growth (Q1), N = 80		Intensifying (Q2), N = 65		All, N = 173	
	dA	*dY*	*dA*	*dY*	*dA*	*dY*
Control classes						
Economic (E)	0.65	0.35	0.39	0.07	0.20	0.25
Demographic (D)	0.56	N.S.	0.20	N.S.	0.34	N.S.
Biophysical (B)	0.33	0.13	N.S.	N.S.	0.31	0.04
(E) + (D) + (B)	0.75	0.36	0.56	0.07	0.48	0.27
Governance classes						
Maximal governance (G)	0.19	0.09	0.08	0.07	0.07	0.09
Marginal governance (E+D+B+G)-(E+D+B)	0.03	0.02	0.00	0.22	0.04	0.02
Sign of relationship	-	+	-	+	-	+

countries in this respect. Furthermore, quality of governance is high in intensifying countries and low in other groups. In between groups, significantly higher quality of governance does not necessarily lead to a significantly higher yield increase, as average yield increases were nearly identical for growth and intensifying countries, which is not shown. However, the between groups analysis does indicate a relationship between lower quality of governance and stronger area increase, for growth and intensifying countries. This means that the lower the quality of governance, the more area increase will occur. The signs of relationships found in the within groups analysis confirm this by suggesting that lower quality of governance is more associated with area increase than with yield increase, whereas higher quality of governance is now also more associated with yield increase than with area increase (Table 3). We also know that quality of governance seems more important to the explanation of spatial variability in area increase in growth countries, and more important to the explanation of spatial variability in yield increase in intensifying countries (Table 3). Therefore, in general, higher quality of governance seems to lead to substitution behavior of land for inputs, rather than increases in yield only. This expands on previous studies that only showed yields to be positively related to higher quality of governance (Fulginiti et al. 2004, Thirtle and Piesse 2007, Lio and Liu 2008). As for the individual governance indicators, it could be seen that the scores on political stability differ from those of the other governance indicators, i.e., relatively low likelihood of destabilization in growth countries, when compared with intensifying countries (Table 2). This indicator is more independent from the others anyway: one may have poor governance but without much violence (Table 2). On the other hand, political instability is unlikely to occur in combination with good governance.

These results suggest that countries with lower quality of governance are more oriented toward expansion, and that rising levels of production are achieved more by area increase than by yield increase. Moreover, as quality of governance becomes higher, this orientation of countries toward production tends to flip from expansion toward intensification. This indicates that it is not possible to prevent further expansion in growth countries, unless quality of governance can be improved. On the contrary, rising levels of production would likely be accompanied by approximately the same amount of expansion as yield growth, in line with other global studies (OECD/FAO 2008, Bindraban et al. 2009, IAASTD 2009). If quality of governance could be increased, results suggest that less cultivated area could be used than at present by growth countries. Furthermore, in growth countries, quality of governance could still rise radically, compared to intensifying countries. Therefore, growth countries appear to have a large potential for further substitution of agricultural production. The intensifying countries, which are generally wealthier and more developed (Fig 2, Table 2) than growth countries, seem to have realized this potential to a large extent already. Moreover, yield increases could be realized more cost effectively in growth countries than in intensifying countries (Marra et al. 2003), as growth countries are generally less developed than intensifying countries (Fig 2, Table 2). That economic and governance indicators appear to interact for yield change in intensifying countries (Table 3), could reflect that intensifying countries are generally higher up on their technological learning curve (Marra et al. 2003). Finally, intensifying countries are less biophysically constrained, which could also be related to a higher level of technology, knowledge, and more effective management.

CONCLUSIONS

It was demonstrated that governance in countries where the agricultural area expands, differs significantly from that in countries where the agricultural area contracts. Governance is more important to the explanation of spatial variability in area increase in less well-developed countries, and more important to the explanation of spatial variability in yield increase in more highly developed countries. This indicates that in the first case governance is more related to expansion, and in the latter more to intensification. Furthermore, our analysis suggests that countries with poor governance are more likely to achieve a production increase by means of area expansion rather than by means of yield increase. Moreover, as the quality of governance increases, this orientation toward production tends to flip from expansion toward intensification. Should we assume a causal relationship, the tendency of expanding cultivated area in less developed countries can be stopped by improving the quality of governance.

Responses to this article can be read online at:
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