

## Paths and Limits of Agricultural Growth

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**Abstract** — The growth of agriculture and its ability to feed growing populations rests on land and labour productivities. We estimated these partial productivities in food kilocalories for most countries of the world, and discussed their evolution over the past 40 years. Very contrasted productivity paths are shown between the 6 macro-regions of the Millennium Ecosystem Assessment.

**Keywords** — Agricultural productivity, Food policy, International development

2003), at the geographical scale of the six regions of the Millennium Ecosystem Assessment (MEA), and according to a simple tautological relationship between land and labour partial productivities:  $\text{Production/Ha} * \text{Ha/Worker} = \text{Production/Worker}$ .

This analysis confirms, updates or extends some works carried out by P. Bairoch [3], Y. Hayami and V.W. Ruttan [4], L. Malassis [5]. It differs from usual literature on agricultural development where productivity challenges are rarely quantified, or for few countries only, or where land productivity is measured through yield changes of some selected commodities (mainly wheat), and labour productivity through added value per worker.

### I. INTRODUCTION

How a decreasing share of the active population will continue to provide food for a growing number of people? with limited terrestrial endowment in mineral reserves and natural resources (land, water, petroleum, phosphates...)? without degrading further ecosystems and jeopardizing the services they can provide for future generations [1]?

Faced with this complex issue, we highlight here that past decades of world agricultural growth rested on very contrasted regional evolutions of land and labour productivities, and that these past regional productivity routes help to better identify questions, deadlocks and opportunities for the future.

To characterize and analyze these different productivity routes, we combined national annual statistics on land-use, on populations and on all vegetal food productions whose annual volumes in tonnes [2] have been converted into calories and aggregated, as explained in part II (Data and Methodology). Part III presents the results in a synthetic graphical way, on a 43-year period (1961-

### II. DATA AND METHODOLOGY

Our historical analysis of world agricultural productivity is based on a 3-step work.

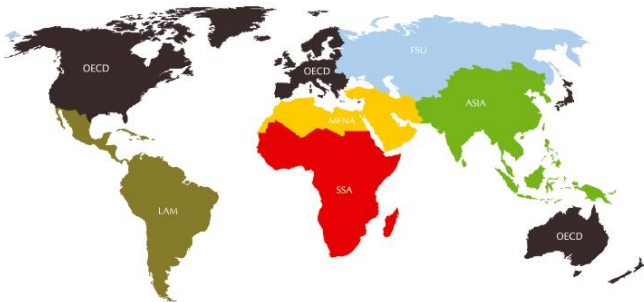
Firstly, FAO annual country-level statistical series [2] on land-use, populations and agricultural productions were bulk-downloaded, merged and checked on a 43-year period, i.e. from 1961 to 2003. During the process, many islands or micro-States had to be removed for missing or erratic statistical information, along with few bigger States such as Afghanistan, Iraq and Somalia. The output database kept ~150 geographical entities out of the ~250 appearing in the FAO databases all along the period, which account for more than 98% of the 2000 world population and of the world land area without Antarctica.

Secondly, an aggregated vegetal food production (AP) were estimated as follow:  $AP_r = \sum_i (P_{ir} * C_i)$ , where  $r$  is a region (or one of its country),  $i$  a vegetal

biomass listed in the statistical series "Commodity Balances" and edible in its primary form (cereal grains, oilseeds, pulses, fruit, vegetables, etc., regardless the final use as food, feed or something else),  $P$  the volume of production in metric tonnes of product line  $i$ , and  $C$  its food calorie content per tonne according to the FAO [6]. The regions  $r$  considered hereafter are those of the Millennium Ecosystems Assessment [1], i.e. Asia (ASIA), Former Soviet Union (FSU), Sub-Saharan Africa (SSA), Middle East and North Africa (MENA), Latin America (LAM) and most OECD country-members in 1990 (OECD) (Fig. 1).

Thirdly, we estimated regional partial land productivities (production per hectare) and work productivities (production per worker) by dividing respectively our  $AP_r$  in kilocalories (kcal) with the regional net area under temporary or permanent crops (hectares), and with the regional total economically active population in agriculture (workers) as estimated by the FAO. Land and labour partial productivities can be interestingly linked and analyzed through a tautological relationships using the "land availability" (ha/worker):  $\text{Kcal/Ha} * \text{Ha/Worker} = \text{Kcal/Worker}$

Fig. 1 The six MEA regions



### III. RESULTS

#### A. Global trends

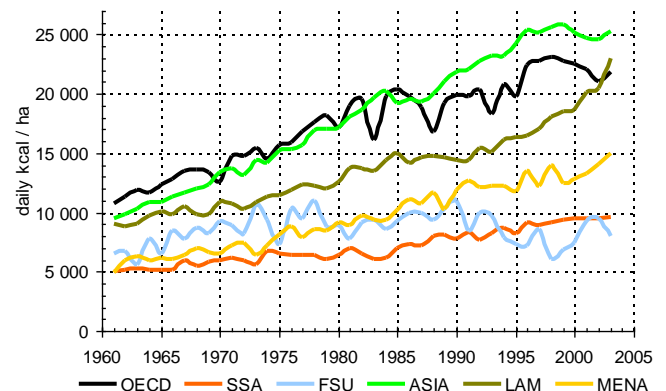
Between 1961 and 2003, the world population has been multiplied by 2 and the urban one by 3; whereas active people involved in agriculture have increased by only 60%. Consequently, the number of persons nourished by an agricultural worker has increased from 3.6 to 4.7 on global average (+ 31%). This was

made possible by an increase of production per worker (+53%) as well as per cultivated hectare (+123%). But because of land constraints, the cultivated area per worker has fallen from 1.45 to around 1 ha.

#### B. Highest land productivity in Asia

In the early 1960's, land productivities ranged between 5,000 to 11,000 kcal/ha/day (Fig. 2). The dispersion was wider in the early 2000's as yields have meanwhile been multiplied by 2 or more, except in FSU. From 1985 onwards, land productivity is the highest in ASIA where credit, irrigation, fertilizers and high-yielding varieties boosted wheat and rice yield as well as the number of crops per year. But there is an apparent levelling off since 1995, as in OECD. On the contrary, land productivity is accelerating in LAM, closing the gap with OECD just at the end of the period. In MENA, land productivity has been multiplied by 3 which is the highest growth rate, whereas it was only by 2 in SSA where no Green Revolution took place as in ASIA.

Fig. 2 Food Veg. Production per Cultivated Hectare



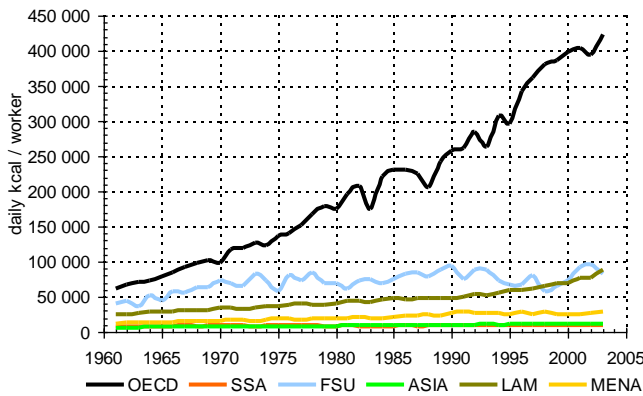
#### C. A labour productivity boom in OECD

The contrast between OECD and non-OECD countries is very impressive as far as the per-worker productivity is concerned (Fig. 3).

This "North/South agricultural divide" is due to motorization (and related fossil fuel use for traction, water pumping, harvest and post-harvest work...), as our proxy "number of tractors" per hectare or per agricultural worker suggests it (Table 1 and Fig. 4

using a log scale and showing everywhere a declining growth).

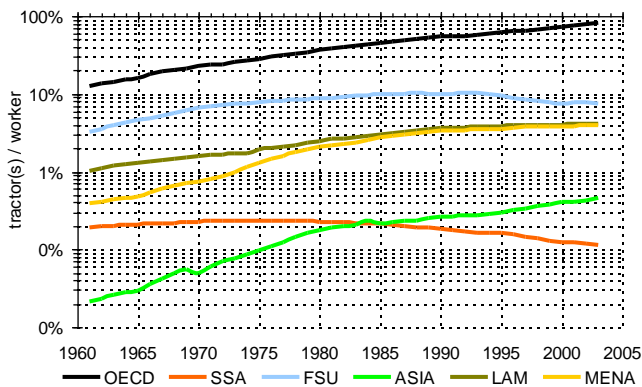
**Fig. 3** Food Veg. Production per Active Agri. Worker



**Table 1** Motorization (year 2000)

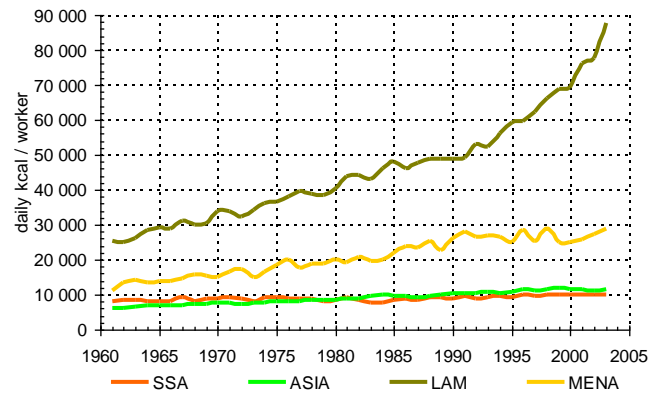
	OECD	FSU	LAM	MENA	ASIA	SSA
Tract / 100 Wkrs	72.0	7.5	4.0	3.8	0.4	0.1
Tract / 100 Ha	4.1	0.77	1.1	2.0	0.9	0.1

**Fig. 4** Tractors per Active Agricultural Worker



The labour productivity of motorized FSU agriculture is quite unstable, and a zoom on less labour-productive zones (Fig. 5) shows an exponential growth in LAM, resulting mainly from a land productivity growth. Finally and surprisingly, ASIA and SSA show similar low performances in term of labour productivity despite large differences in land productivities: land availability has also to be taken into consideration.

**Fig. 5** Food Veg. Production per Active Agri. Worker



*D. Large disparities in land availability*

The average (net) cultivated area per agricultural worker is another illustration of the agricultural divide (Fig. 6). It is the result of non related evolutions of active population (Fig. 7) and cultivated land (Fig. 8). In ASIA, active population in agriculture seems to stabilize around 1 billion people, whereas it is still increasing in SSA. Elsewhere, this population is either stable or declining. As far as area under cultivation is concerned, it has increased only in ASIA, LAM and SSA, but at the expense of two carbon and biodiversity pools, forests or permanent pastures.

**Fig. 6** Cultivated Hectare per Active Agri. Worker

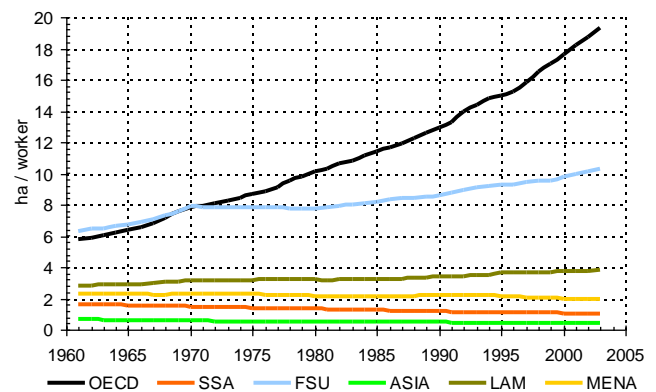


Fig. 7 Active Agricultural Workers

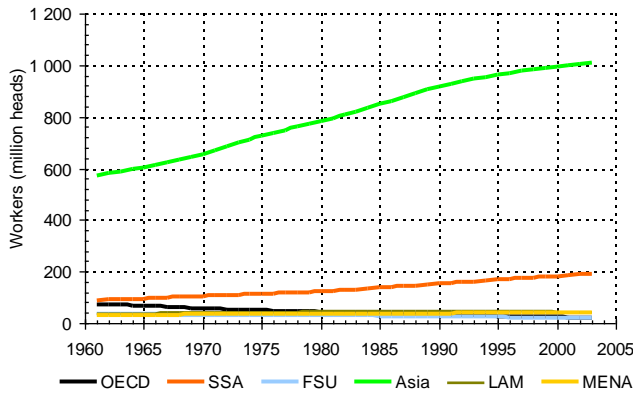
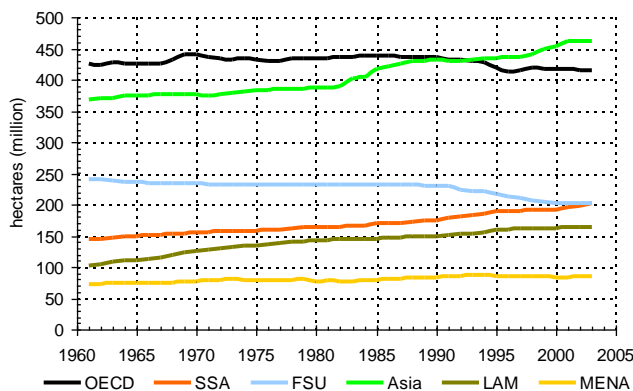


Fig. 8 Cultivated areas



#### IV. IS THERE A SUSTAINABLE AGRICULTURAL PRODUCTIVITY PATH?

Thanks to a million data from FAO, we can provide a very synthetic view of the past 40-year agricultural productivity routes of 6 world macro-regions. As shown in Fig. 9, each of these regions followed a specific path, resulting from limitations in land availability (X axis) and ability to increase land yields (Y axis). Despite a fantastic OECD's growth in terms of labour productivity due to motorization and quite

easy rural-urban migrations, the world average agricultural productivity path remain rather close to the ASIA one based, above all, on a yield boost. This land productivity is high in ASIA as well as in OECD, but in both cases, seems now to level off for various reasons (low market or political incentives, increasing prices of fossil energies and of other agricultural inputs, water stress, soil or biodiversity erosion...). Future important yield growth may take place in FSU where both land and labour productivities seem still rather easy to improve. In LAM where the last two productivities are already significantly high, the extension of the cultivated area may be the first challenge and problem (erosion of global carbon and biodiversity pools...), while in SSA, peaceful land access remains a key question, along with mechanisation and yields improvement.

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Fig. 9. Regional Agricultural Productivity Paths (1961-2003)

