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ENERGY AND AGRICULTURAL PRODUCTION
Sustainability of Biofuels

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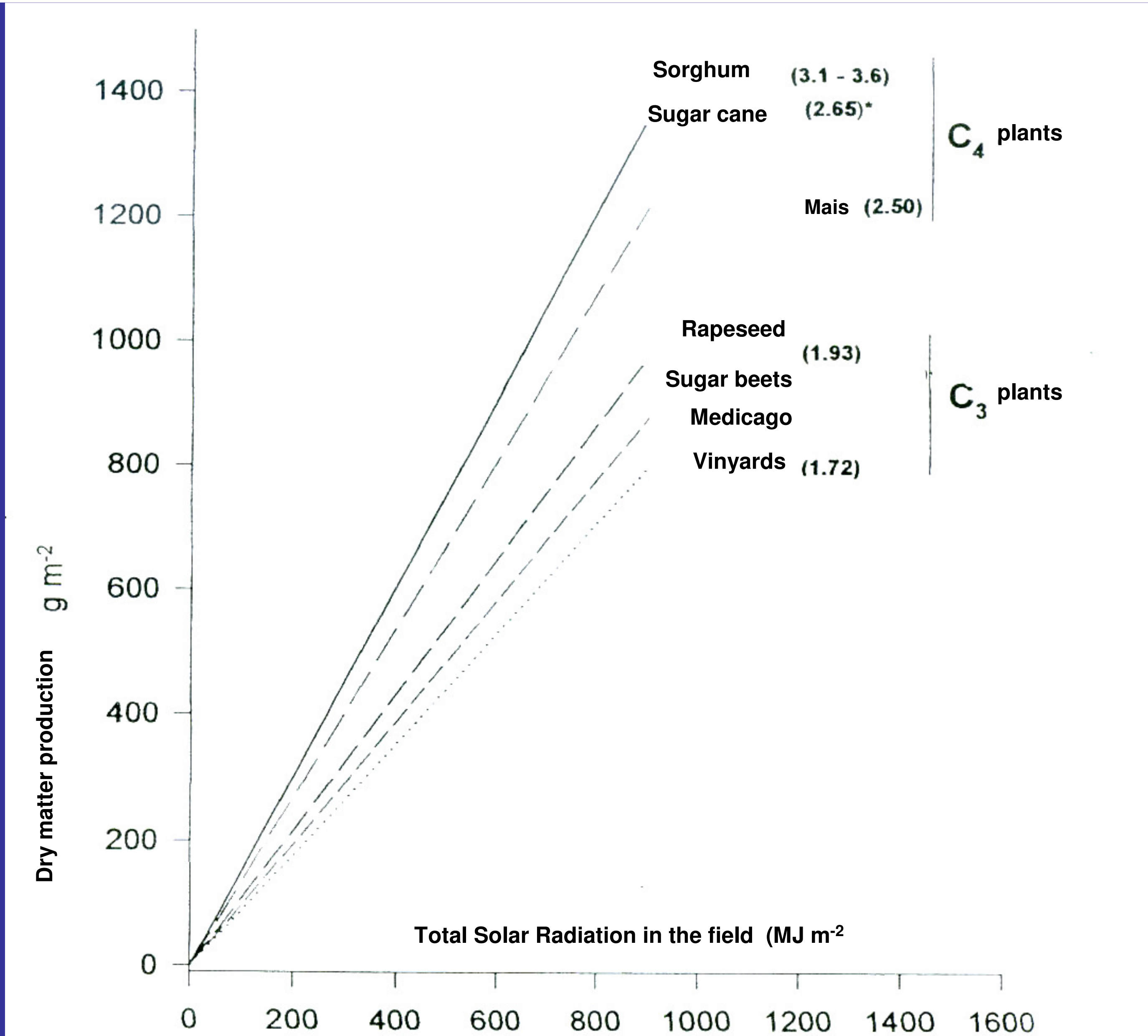
Relation between energy inputs and plant production

The Energy systems related to plant production (Biomass production) is very close related with the Total Energy inputs during he life cycle of a plantation.

The total Energy inputs are coming:

a) passively, from the Solar Energy inputs
b) actively, from the commercial and non commercial energy (agricultural
energy) inputs given by the farmer.

Solar Energy activates photosynthesis, a mechanism that practically means the storage of the solar energy inputs in form of biomass (efficiency between ~1-3%)



Source: Gosse et al. (1986)

Fig. 1. Dry matter production in relation to the induced total solar radiation in the field

Agricultural Energy inputs (commercial and non commercial Energy)

=

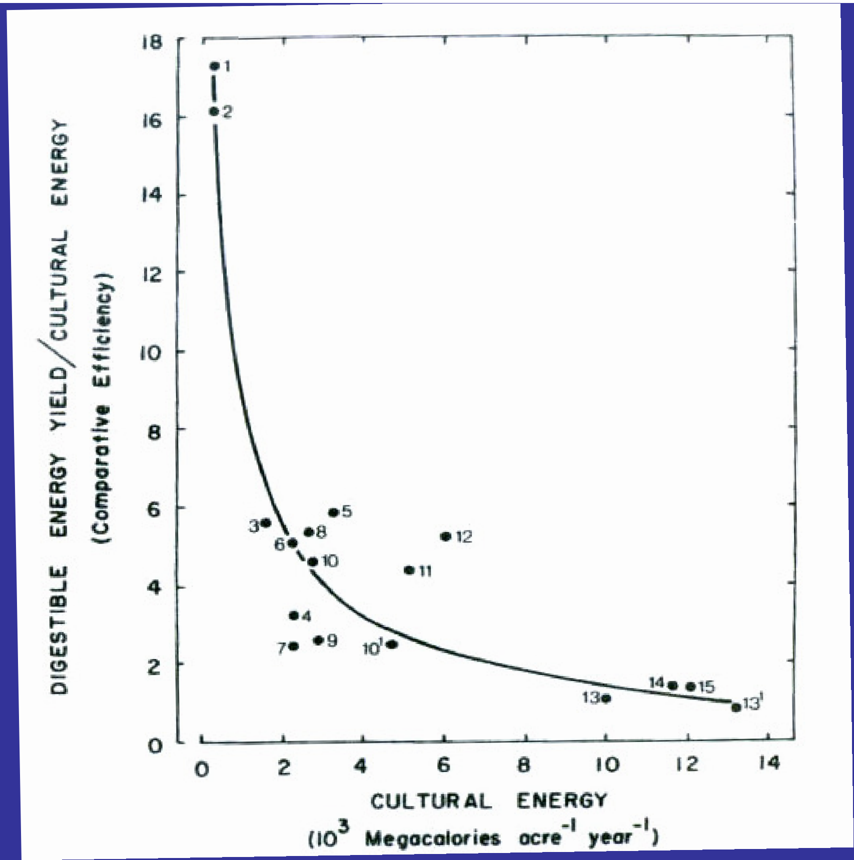
Direct energy inputs (Labor, Fuels, etc)

+

Indirect energy inputs {water, chemicals etc)

The relation between Agricultural Energy inputs and the biomass production (Energy output) follows the two classical for the production rules, especially concerning the fertilizers.

1. The rule of the **non analogical relation,** between energy inputs and energy output (biomass production)
2. The rule of the **minimum** of the inputs. The maximum energy output (biomass production) is close related with that element of the different energy inputs, that is limited in the minimum amount.



Sources: Handbook of energy for world agriculture

Fig. 2. Efficiency of energy use in 15 agricultural systems. Cultural energy is the energy input to produce crops, except solar energy and including human and animal work; fossil fuel used is production, processing, and transport; and energy required to grow seeds, construct buildings, and produce machinery, chemical, and fertilizer. **1**. Paddy rice, Philippines, 1970, **2**. Vegetable garden, New Guinea, 1962, **3.** Corn for grain, Iowa, c 1915, **4**. Corn for grain. Pennsylvania, c.1915, **5**. Corn silage, Iowa, c 1915, **6.** Alfalfa-brome hay, Missouri, 1970, **7.** Oats, Minnesota, 1970, **8**. Sorghum for grain, Kansas, 1970, **9**. Soybean, Missouri, 1970, **10.** Sugar cane, Hawaii, 1970, cultural energy excludes processing. **101.** Sugarcane, Hawaii, 1970, cultural energy includes processing. **11.** Corn for grain, Illinois, 1970. **12.** Corn silage, Iowa, 1970, **13.** Sugar beets, California, 1970, cultural energy excludes processing. **14.** Peanuts, North Carolina, 1970. **15.** Irrigated rice, Louisiana, 1970 (source: Heichel, 1973).

These two rules are the key factors of the role of energy for food production or for biomass production in general.
More energy input to the production system, more food production, or more energy output, **but not analogical** and to a certain point (see fig. 2)

If water or a fertilizer input is limited, to a minimum amount, food production or energy output, will be limited to that factor, regardless if other energy inputs are given in abundance.

1st Conclusion**:** Poor developing countries they don't have access to energy (fuels, fertilizers) in order to develop their agricultural production, even though for them a minimum energy input could assure multiple energy output (more food etc)

Energy for Subsistence and Development

The subsistence level is that which barely sustains life, i.e food production and preparation, protection from the elements, transportation of water and food, etc.

Development requires more energy, both commercial and noncommercial, especially for jobs creation and so, more money for better **subsistence level**

Table 2: Commercial energy required for rice and corn (maize) production, by modern, transitional and traditional methods (modified from Chanceller, B.A. Stout, 1990)

	Rice		**Maize**	
	Total Energy input (10^6Joule/ha)	**Yield (Kg/ha)**	**Total Energy Input (10^6Joule/ha)**	**Yield (Kg/ha**
Modern Systems	64885	5800	30034	5083
Transitional Systems	6386	2700	-	-
Traditional Systems	173	1250	173	950

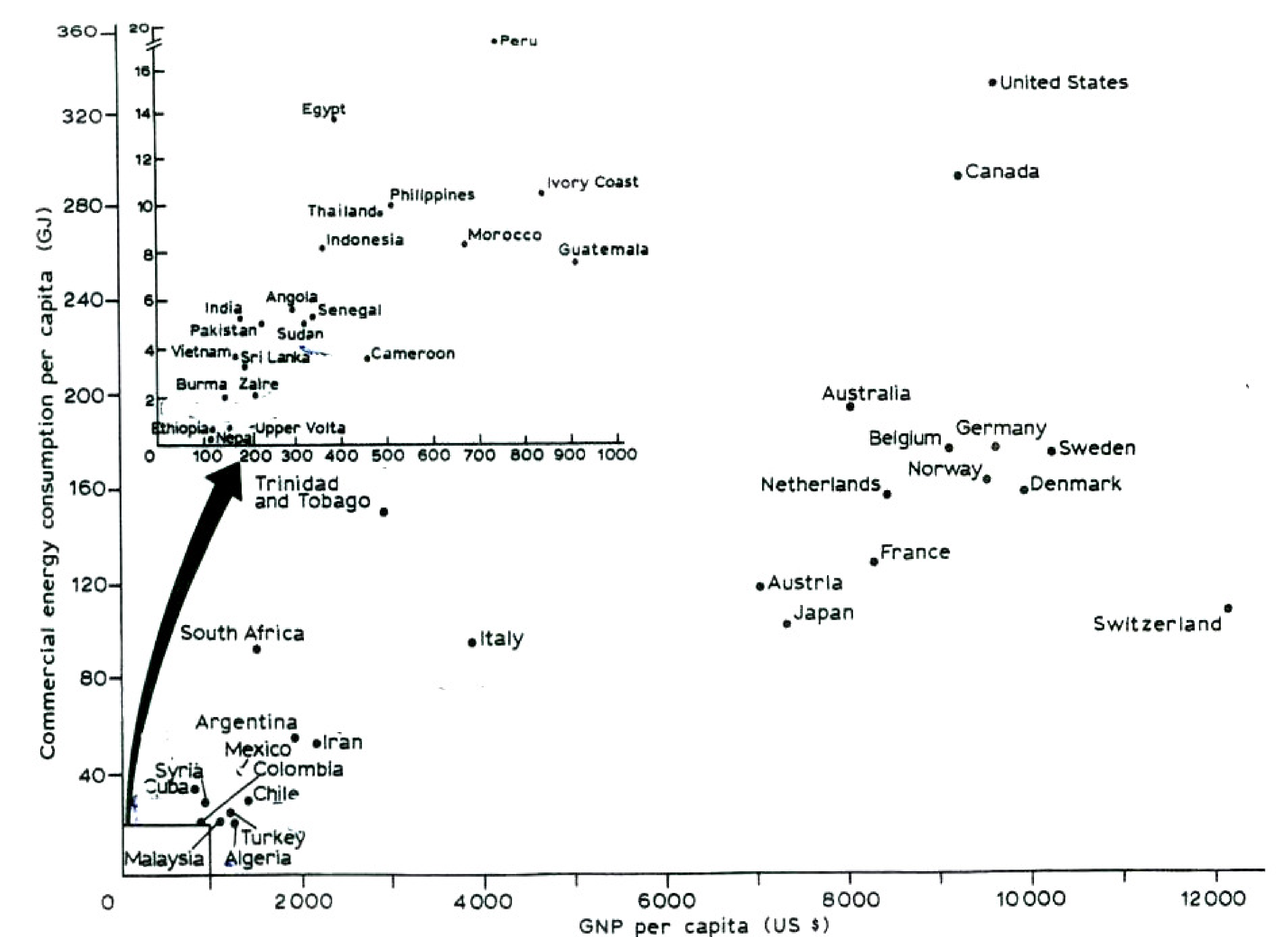


Fig. 3. **Relationship between commercial energy consumption and GNP for selected countries (source: Mudahar & Hignett, 1982; World Bank, 1984c)**

***2nd Conclusion*: Countries spending more energy offer to their population better jobs opportunities and thus their population can spend more money for better living conditions**

BIOENERGY OPPORTUNITIES

The Energy efficiency, or the ratio: Energy output: Energy input, of a biomass plantation is depending mainly on: 1) plant species, 2) meteorological conditions, 3) soil and water conditions, 4) the intensity of the energy input

Table 3 : Energy efficiency in different agricultural systems (F.A.O)

Agricultural System	Minimum area/inh Ha	Man power inputs %	Biomass production Mj/man.hr	Energy ratio Energy output: Energy input
Not Industrial (Africa)	10.0	70	11-30	13.0-40.0
Hemi industrial (Latin America)	2.5	40	30-40	5.0 – 10.0
Industrial North America, European	0.1-0.3	4-12	3000-4000	0.5 – 4.0

If one calculates the total energy outputs (crop + straw) in the wheat production, we can obtain en. ratio 9/1 - 5/1, to the tradit. farming systems, and up to 3/1 - 2/1, in the today farming systems, in the dev. countries.
Other examples of biomass production efficiencies are:

Eucalyptus (under good water conditions) in central Africa	>15/1
Cynara Cardunculus(Dry conditions central Greece)	>10/1
Eucalyptus (under dry conditions, in Crete,Greece)	3/1
Arundo donax (under good soil conditions) in Kopais-Gr	7/1
Sugar can in Brazilia	7/1
Sweet sorghum (under good soil conditions and 250 min water in Greece)	5/1
Corn average in U.S.A (without use of straw)	>1/1
Rape seed	3/1

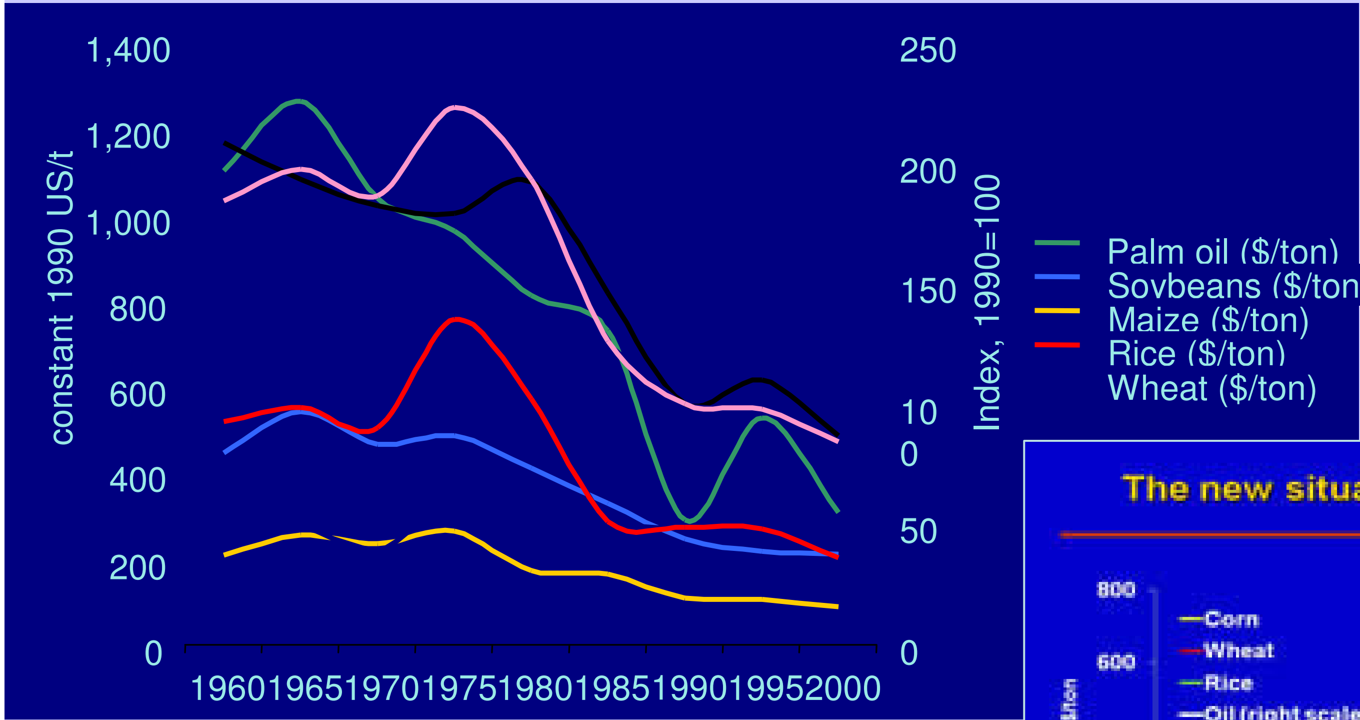
3rd Conclusion

In cultivated biomass, with a very positive efficiency (>3/1), the farmer can produce energy not only to cover the energy inputs for more food production per cultivated area, but also to cover the energy needed for a certain development, of course under certain limits, depending on the cultivated area/inh. and local conditions.

The competition between Food and Bio-Fuel.

*more energy inputs $\Rightarrow$ more food/hectare
*more energy in the society $\Rightarrow$ more jobs $\Rightarrow$ better living standards

Recent food crisis gave floor for long discussion and problematic around the world, on the Opportunities and Threats from Bioenergy expansion.



Muller et al. (2008), Water Policy 10 (Suppl. 1): 83-94

Food not more expensive than energy !!

Fig. 4. Food prices evolution it was negative up to recent years

- F.A.O estimations support that the influence of biofuels development on food prices, recently had contributed only by 10% and not by 65% according the world Bank estimations.

- Internationally, areas cultivated by Cotton (34 M.Ha), by tobacco (4 M.Ha) and by many other non food industrial crops, not only they didn't rised, up to now, any worry for food security, but on the contrary these crops had contributed a lot to support development, both in agricultural and urban regions.

- Following CAP, in Greece, we had a reduction in tobacco plantation, from ~0.4 M.Ha before 2003 to less than 0.2 M.Ha 2007, offering this way 0.2M.Ha of land to food production. The result is the misery to the tobacco farmers, to some local S.M.S.E and damages in a certain point, to the National Economy

- The global production of the main food products is always growing, following the demand and there is no reason to stop growing, thanks to more energy inputs.

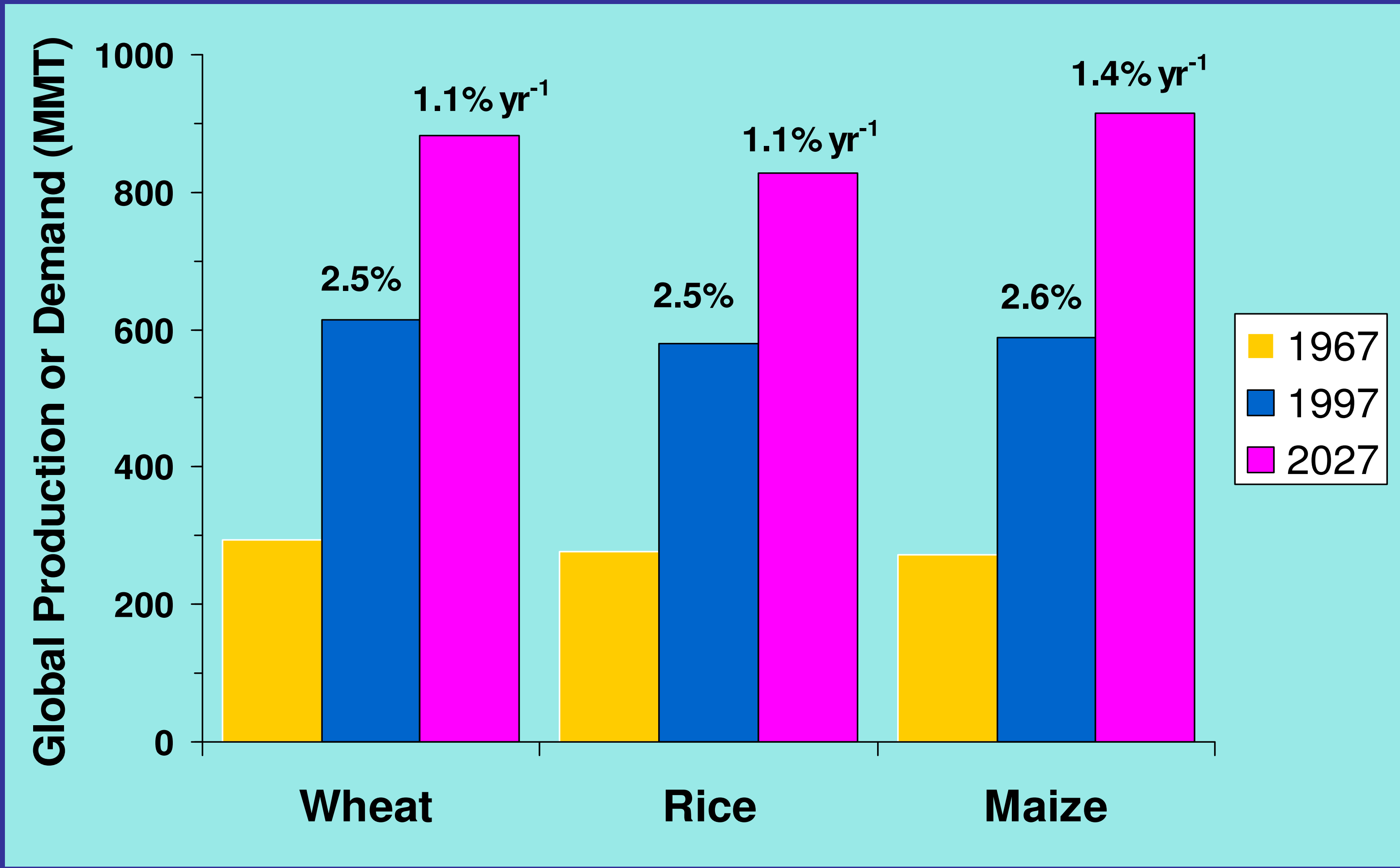


Fig. 5. Growth in Grain Supply – Demand *(Source: IFPRI)*

Table 6. Demand for biofuel and potential supply

- **Bioenergy demand:** affected by rising oil prices, government policies, global markets, etc.

  Global primary energy supply: 463 EJ (Exa =10^{18}) in 2004 and > 850 EJ by 2050

- **Bioenergy supply (theoretically):**

  - global photosynthesis is estimated at 3-4,000 EJ

  - potentially economically viable by 2050: ~ 400 EJ

  - converted to liquid biofuel it amounts to ~50 EJ

  (NB: current use of biofuels for transport: 0.9 EJ in 2005 ~ 1%)

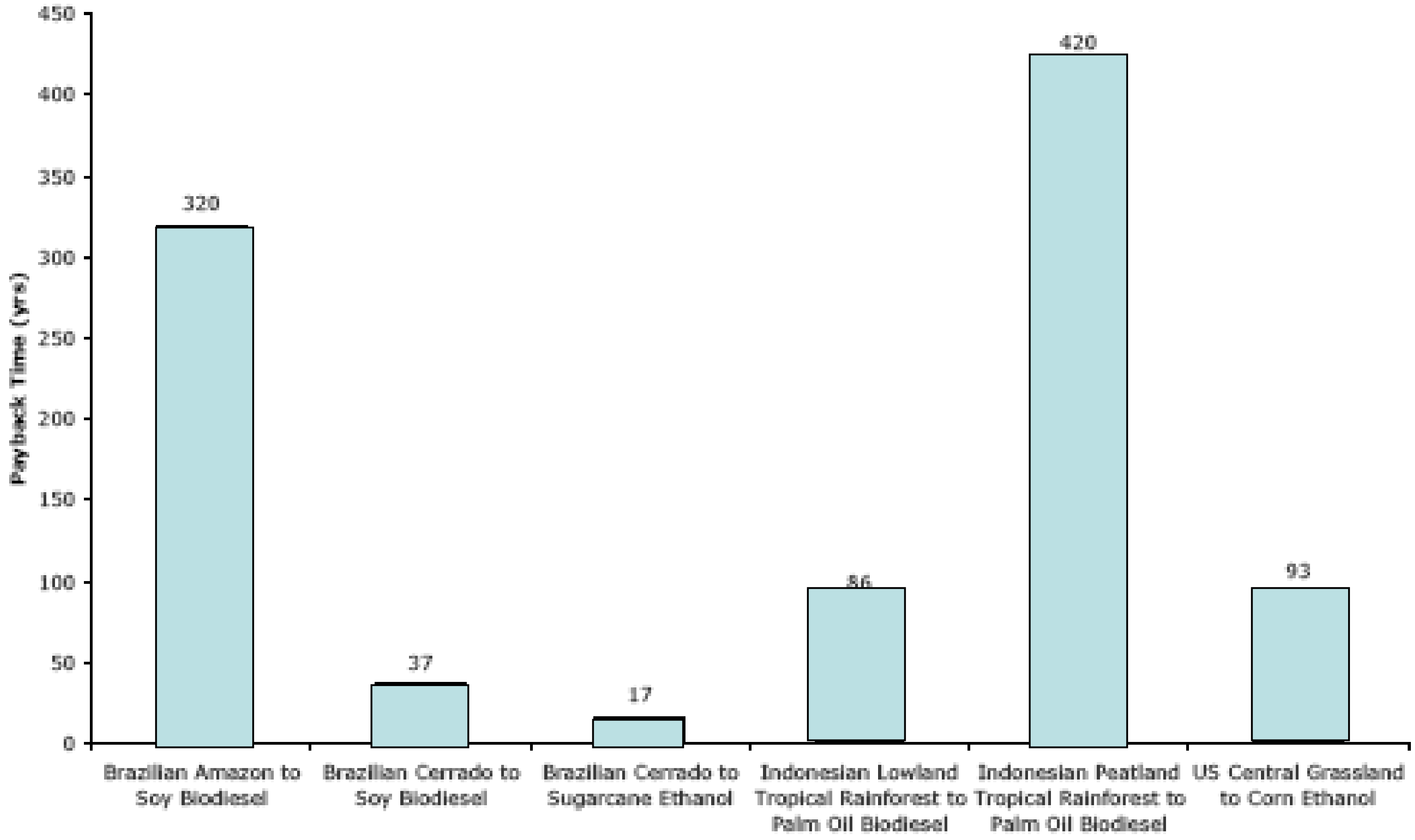
Source: H. Spiertz, 2008

BIOENERGY THREATS ON SUSTAINABILITY

Even though the recent energy production from agriculture had a very small influence on recent food crises, which was devoted mainly to phychological reasons and to the inertia, characterizing the production systems (at least one year), there are many question about the sustainability rules that bioenergy follows so far and many questions about the future threats from bioenergy

First Generation Biofuels

Environment at risk



Source: Fargione et al (2009)

Fig. 6. Pay-back times for different biofuels and land-use changes

Table 7: Relative performance of US and Brazilian ethanol

	US ethanol	Brazilian ethanol
Typical GHG savings*	~20 per cent	~90 per cent
Typical energy balance	1.5	8
Yield (liters per hectare)	3.100	6.500
Typical cost per liter	$0.56	$0.42
**GHG savings excludes any effects duo to land-use change*		

Source: World watch Institute (2007)

U.S. corn production is a heavy user of nitrogen-based fertilizers, the true emissions of which we may only now be starting to understand, and the run-off (via Mississippi) from which is creating a “dead-zone” of 20,000 Km2 in the Gulf of Mexico, (2008, National Journal of Science).

The USA accounts for about 40 per cent of global production. 2007, about a quarter of the US corn harvest went to ethanol. This means that the US ethanol program will consume about 12 per cent of global corn production, and displace about 6 per cent of US transport fuel. (USDA, Feb. 2008).

Bioenergy threats on land rights and local employment

The biggest advantage of biomass use for energy is its social character, that means energy raw material has to be produced locally, covering in cost the ~60% of the final cost of the energy produced from that raw material.

A cost that normally has to be given to the local farmer.
But how true is this practice?

Access to land is a fundamental precondition in realizing the potential role of agriculture in reducing poverty. Unfortunately, one of the side effects of biofuel targets- is a “scramble to supply”, in which companies or rich and powerful investors rush to buy up new land, potentially displacing vulnerable communities whose rights to the land are poorly protected. The UN has identified 60 million indigenous people at risk of displacement for biofuels.

We have such examples from India, Tanzania, Indonesia and Brazilia, where investments are flooding into the Brazilian sugarcane industry – from 2008 to 2012 they are expected to total $33bn, over which time the share of plants under foreign control is expected almost to double.

The Brazilian Renewable Energy Company's (BRENCO's) investors are coming from everywhere and they have international influence and power.

Despite this high level of involvement, following an inspection of its operations in the State of Goias by the Ministry of Labour, in 2008, BRENCO was found to be employing workers in degrading conditions.

Next-generation bio-fuels, poverty, and development

The problems associated with the current generation of biofuels we believe that is a short transition on the way to a brighter future of “next-generation” fuels, produced using new production pathways not yet commercially available. Examples includes the production of ethanol or biodiesel from lignin and cellulose, which could allow us to use trees, grasses, algae, organic wastes and residues, as feedstock’s.

It is argued that bio-fuel targets are necessary to provide industry with the assurances it needs to invest in next-generation, which will have fewer adverse impacts on poverty and the environment. But is this necessarily the case?

Although yields are likely to be higher, many next-generation technologies may still pose similar problems, because they will depend on large-scale monocultures that threaten biodiversity, food production, (even with algae) land rights, or labor over exploitation.

Just because a next-generation biofuel does not use food as a feedstock, it does not necessarily mean that it does not threaten food security: it may still compete with food for land, water, and other agricultural inputs, as higher yields will likely translate to higher targets. The European industry is already looking for a 25 per cent biofuel target by 2030 in anticipation of next-generation fuels becoming commercially available by then.

Technologies that do not require extensive monocultures, and therefore do not put food production or vulnerable people’s land rights at risk, will present the least risks to poor people. Therefore biofuels produced from municipal waste, crop residues (as long as sufficient residues are left to enrich the soil), or non-arable feedstock such as algae, may present the most promising avenues for sustainable development.

4th Conclusion(as Jacques Diout, Director General of FAO said):

“Biofuels present both opportunities and risks and the challenge is to reduce or manage these risks, while sharing the opportunities more widely”

Bioenergy: opportunities and threats

- Opportunities
  - Contributes to a decrease of GHG emission globally, expecting to be better in the 2nd generation biofuels
  - Makes societies less dependent on imports of fossil fuel
  - Offers agricultural and industrial development opportunities, contributing to ameliorate the subsistence level
  - Offers investment opportunities in rural areas (if the investors are limited to transform biomass to energy products)
  - Waste-water re-use opportunities
- Threats
  - Food availability and security are at stake without the proper international and national policy
  - Loss of biodiversity and virgin land
  - More volatility in agrimarket prices
  - Loss of the social character of biomass ,with the implication of the investors to the biomass production directly
  - Over exploitation of rural population

General Conclusions

- The use of all the organic wastes and plant residues as feedstock (energy, chemicals, fiber, building material, compost), and plus an annual increase of crop productivity (~2%), are needed to secure food, feed and biofuel production

- Besides the appropriate international food security Policy, measures have to be addressed on a regional scale, because of the uneven distribution of natural resources; especially land and water.

- It is positive and to the right direction, the measures taken by E.U. in its last directive 11-12 December 2008, on R. Energies(The year 2020, Energy from RES in **all** E. Countries should be 20%). In these 20% RES target, Biomass is expected to contributes by 12,5% (EREC 2008)

  E. Union regulation, supports also the use of feedstock **not destinated for food** and respecting the **new sustainability criteria,** saving initially at least 35% of CO_2, and up to 2017 more than 50%, with the existing installations (<1/4/2013), and more than 60%, for the new installations.
  Bioenergy feedstock should not produced: 1) in land of high biodiversity, 2) from natural forests 3) from places of high C concentration (Savannas, Peat etc.)

- In any case, the cost of biofuels will continue to be tightly related ,first with the prices of fossil fuels and secondly with the food, feed, and fiber prices.