The Oil Drum: Europe
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The World's Expected Carrying Capacity in a Post Industrial Agrarian Society

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This is a guest post by **WisdomfromPakistan**. Wisdom is a computer engineer living and working in Karachi, a cultured city of some 20 million people. He has been conducting his own research into human nutritional requirements and the Earth's carrying capacity which he now wants to share with The Oil Drum readership.

As peak oil approaches, shortly followed by peak gas and eventually peak energy, we have to retreat to agriculture as the prime energy producer in society. Post-peak agriculture will be radically different to modern agriculture. Today's agriculture is more an energy consumer than an energy producer. In developed countries it takes ten calories worth of energy from fossil fuels put into a farm in the form of fertilizers, pesticides and transportation fuel, **to get one calorie back in the form of food** (**see also here** and **here**).

Happy children fetching water

Some of this input can be reduced by localization, which cuts considerable expenses in the form of transportation fuel, but other expenses like fertilizers and pesticides can't be reduced without having a considerable reduction in food production. A detailed look on the situation, how we got here and an account of agricultural productivity before industralization is therefore necessary.

Up untill 1950 the World's agriculture was mostly run on organic lines with no artificial chemicals put into the soil. After the Second World War efforts were made to dump the large amount of chemicals made for military purposes into farm chemicals. In the 1960s, with the advent of **the green revolution** world agriculture slowly transitioned to an artificial fertilizer base. As a result, food production increased 2.5 times on average. This increase in productivity comes from higher nitrogen absorption, selective cropping and high grain-mass to plant-mass ratio.

Higher nitrogen absorption means more water use. This was supported with intensive dams construction along with canal systems to have enough water in winters to have two crops per year.

Higher grain-mass to plant-mass ratios mean less crop residue available for animals as a larger part of the plant is now eaten by people.

Selective cropping

Selective cropping means only high-yield varieties are grown. This reduces resistance against pests as miles and miles of the same crop variety is an easy target for pests. To compensate, a lot of pesticides are used. It also means reduction in crop-diversity. For example in China in 1949 about 10,000 varieties of rice were grown, in 1970 it reduced to 1000, in 2002 that further reduced to 300. The 14 leading varieties occupy **more than 40% of chinese wheat fields now**. India had 30,000 different types of wheat, now 90% of the wheat acreage is covered by 10 different but highly productive varieties ("Saving Crop Diversity Key to Winning War On Hunger", Reuters, 7/3/01). Out of 700 crop species that have been domesticated by humans, only 30 species now provide 90% of the global food intake. (FAO, "The State of the World's Plant Genetic Resource for Food and Agriculture", Rome, 1997, p 14).

As in all systems, efficiency was gained at the cost of resilience, as low productive but more shock-absorbing components were taken out of the system.

World's average wheat production used to be 400 kg per acre per year in 1950. By the 1970s this was boosted up to 2000 kg per acre per year in South Asia and 4000 kg per acre per year in Europe and the USA. That is one of the reasons the world was able to compensate for rapid increase in population. In 1950 world population was about 3 billion, it is more than double now, but world's agricultural land area is about the same. Also, the world's diet shifted from a mostly vegetarian diet to a more meat based diet. Now, there is no more increase in agricultural productivity that the green revolution can provide and the World population is still increasing. Not much unused agrarian land is available. As a result per capita agriculture production is starting to decline.

Energy needs and a balanced diet

The basic need of humans is food. We need food to have energy to perform vital body functions, to reproduce, to work and to have fun. The unit of energy used by dietitians is the Calorie (or kilocalorie), that is, 4200 joules of energy, enough to raise the temperature of one kg of water by one degree celsius.

The energy need of a typical adult is 2500 Calories per day. Children and elderly need less than that. That brings the average to 2000 Calories per day for all. The calculation can be done **here**.

The caloric values must come 55% - 60% from carbohydrates, 12% - 15% from proteins and 33% - 25% fats. The variation based on climate, culture and personal preferences. For our calculation we take the most recommended 60% from carbohydrates, 12% from protein and 28% from fats. It must be kept in mind that this is an attempt to summarize highly complex and variable data into a meaningful format. There are hundreds if not thousands of food items available for human use, which particular item one uses depends a lot on one's religion, culture, climate, personal preference etc. Food productivity differs a lot on the basis of geographical location.

A scheme of balanced daily diet (link to Excel file):

	Kgs / year
Grains & Cereals	100
Milk	100
Fruits	100
Vegetables	25
Meat (goat, horses, sheep)	25
Oil	12.5
Sugar	12.5
Dry Fruits / Eggs	12.5
Spices	12.5

Average worldwide food output kg per acre per year before green revolution:

	kg per acre per year
Grains & Cereals	400
Fruits & Vegetables	800
Milk	200
Meat (goat, camel, horse)	50
Meat (fish, chicken)	100
Oil	200
Sugar	200
Dry Fruits / Eggs	200
Spices	200

Land needed per person in sq meteres:

	sq meteres per person
Grains & Cereals	1000
Fruits & Vegetables	500
Oil	250
Sugar	250
Dry Fruits / Eggs	250
Spices	250

Pasture	1000
Cotton, tea, coffee, wool etc.	500

Notes:

4000 sq metres = 0.4 hectares. 1 hectare = 2.47 acres. Therefore, land required per person is roughly 1 acre.

• It is estimated that egg production in kg would be at least twice than chicken meat per acre. That is because of the savings in energy when eggs are directly used in diet that would otherwise be used by the chicken in its life time, after it hatches out of the egg, grows up and gains weight up to age of a few weeks before being finally slaughtered.

• Land needed for vegetables is so little (25/ 800 * 4000 = 125 sq meter) that a side crop along with grains/cereals can be grown for that. That’s the traditional Chinese method of having a crop of vegetables along with rice. A nitrogen-fixing crop is needed anyways as a side crop on land where grains/cereals are grown to maintain soil fertility.

• A quarter acre dedicated to pasture grows 200 kg of fodder per year. The total fodder requirement for milk and meat is 400 kg. It is because 2 kg of fodder is needed to have 1 kg of milk and 8 kg of fodder is needed to have 1 kg of goat/camel/horse meat. The other 200 kg of fodder comes from crop-residue, leaves etc from grain/cereals, fruits and vegetables. 100 kg of grains/cereals leave 160 kg fodder, 100 kg fruits leave 200 kg fodder, 50 kg of miscellaneous (oil, sugar, spices and dry fruits) leaves 80 kg of fodder. Assuming it would have half of the caloric values left when finally consumed by animals that is equivalent of 200 kg of fodder.

A simplified division of land is as follows:

Farm (for grains/cereals)	Quarter acre per person
Pasture (for growing fodder)	Quarter acre per person
Orchard (for growing fruits)	Half-Quarter acre per person
Farm (for tea, cotton, wool)	Half-Quarter acre per person
Oil (for veg oil)	Quarter-Quarter acre per person
Sugar (honey or sugarcane)	Quarter-Quarter acre per person
Dry fruits	Quarter-Quarter acre per person
Spices	Quarter-Quarter acre per person

Water

Water is another important factor in farm productivity. A land rich in organic material and minerals is of no use without a supply of water. The primary source of water is rain falling directly on land. Secondary sources like canals are also used to increase productivity. Finally tertiary sources like wells and tube wells are used which to some degree recycles the water already used at the farm.

A 10 inch rain fall on one acre means 1000 tons of water. For a summer crop, at least in my part of world 80% of rain falls during the monsoon, right when the crop needs it. **So 800 cubic meters of water directly from rain is enough** (same Excel file as before) to grow the food per person per acre using **these** water requirements (see also **here**), assuming 20% loss of water at the farm due to evaporation and soil absorption before being used by plants. The calculation includes water needed for world average use of 3.5 kg **cotton**, 1.1 kg **coffee** and 0.5 kg **tea** per capita per year.

If canals are used an additional 800 meter cube of water (one acre ft with 33% loss between dam and farm because of soil absorption, evaporation etc) is available per acre to support two people per acre.

Carrying capacity

Lets try to estimate the World's carrying capacity based on the above mentioned diet. The world land area is 150 million sq km that means about 37.5 billion acres. **10 percent of it can be used to grow grains.** 10 percent as pasture land and another **20 percent as forests to raise animals on**. Altogether 15 billion acres are useful for food production.

Those 15 billion acres can be used to grow food for total 15 billion people sustainably provided:

1) There are no other species than humans.
2) Human population is distributed in such a way that more people live where there is more arable land.

Out of 4 million species of plants and animals today, we are just one specie. There are many species of animals, birds, insects that we need for our survival. For example, some of them eat others to keep their numbers in check. Some like honey bees are needed for pollination without which food production would be very low etc.

Human population is not distributed on the basis of where arable land is. In Australia and Canada 20 million people live in 9 million sq km, about 2.5 people per sq km. In the Indian sub-continent at least 1.2 billion people live in just 4 million sq km, 300 people per sq km. So, at some places there is much less arable land available per person and vice versa in other places.

Today, out of total food production of this planet, humans consume 40%. That confirms that total life support on the planet is 15 billion people (or other animal, insect, bird species of same mass).

Assuming that we can sustainably use 40% of world's food production for our use leaving the rest for all other species, we can have food for 6 billion people on this planet if our population is distributed evenly. Since it is not, long term human population support on this planet ranges from 2 billion to 4 billion. Taking the average 3 billion, this is roughly the population of the world at the end of the second world war.

How to increase productivity

If crop-residue can be saved in a better way, so that most of its caloric values are retained, the need of pasture would be eliminated, saving a quarter of acre. Also, in a culture that use more rice than wheat more land can be saved as rice productivity is typically thrice that of wheat, without destroying the soil. Both of these together can reduce per capita land requirement to half an acre.

If two crops can be grown instead of one, by using excess water from canals and underground, productivity can be doubled.

In more fertile lands with crop output double than world’s pre-industrial average, half the land would be needed per capita. Looking at the large picture, the increase in productivity in more fertile land is mirrored by decrease in productivity in less fertile land. “The magic of big numbers”. So this is not a large scale solution.

In short per capita land requirement can fluctuate between 4 acres in feudal ages of middle Europe (where half the land was kept fallow and on other half output was half that of world’s average) to a quarter acre in a rice-eating vegetarian culture. For the world as a whole, it’s safe to assume the average to be 1 acre.

Conclusion

In the detailed discussion above we found out that long-term, average-diet, pre-industrial, per capita arable land requirement is 1 acre. We also found that using 40% of all food produced in the world (currently consumed by 4 million species of plants and animals) that 6 billion people can be supported on Earth. Since human population is not distributed on basis of availability of arable land, in reality only 2 billion to 4 billion people can be supported. An educated guess is 3 billion, the population of humanity after the Second World War and before the green revolution.

What will happen to the surplus population is a matter of mere speculation. Since fossil fuels will not decline in one day one can expect a gradual decline in population either right after peak energy or over a period of time.

How the population declines is also a matter of mere speculation. In a poorer world higher birth rates may be expected, as is observed in developing countries vs developed countries. So, the decline is more likely to come from reduction in health care with a reduction in life expectancy and an increase in infant mortality.