Agriculture's ESG impact

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Abstract

Nowadays, environmental problems are becoming more and more serious and urgent to deal with. We cannot deny the impact of food and agriculture in general, on the environment. If we consider what we eat and how we grow it, we would find extensive damage to the environment (green gas emissions, soil depletion etc.) and also the wildlife (due to pesticides, fertilizers etc.). We are looking to use the data provided by FAOSTAT giving access to over 3 million time-series and cross sectional data relating to food and agriculture all over the world and try to generate insights and stories on the evolution of different socio-environmental factors such as the correlation between greenhouse gas emissions and agricultural growth for example. Through this work, we hope to gain a deeper insight on the evolution and the environmental impact of agriculture and food.

I. Introduction

The current food system feeds the great majority of world population and supports the livelihoods of over 1 billion people. Observed climate change is already affecting food security through increasing temperatures, changing precipitation patterns, and greater frequency of some extreme events. About 21–37% of total greenhouse gas (GHG) emissions are attributable to the food system. [1],[2]

Therefore, it is mandatory to understand the effects of worldwide agriculture systems on the earth as well as its connections to our daily lives. Assessing the impact of food production and finding solutions to decouple the evolution of the agricultural system with the increase of the GHG is one of the main challenge of our societies.

II. Emissions related to the agriculture type

By exploring the relations between the agriculture and the emissions of greenhouse gases, we observe that the increase of the area harvested for different crops is not constant and not as important as the evolution of the population over the three last decades. This could be explained by the industrialization of the agriculture which goal is to be efficient.

To support this hypothesis, we compare two emerging countries with three already well developed countries. The choice of these countries is detailed in section III. However, we cannot demonstrate a clear change in the areas harvested, in any of these countries.

We can now compare the culture of specific crops in these countries. The mean area harvested of each crop over the three past decades is shown in figure 1, on the left. Except for soybeans, China and India are always the countries that harvest the most of each crop. This can be compared with the graph on the right on figure 1, that shows the emissions per unit of area and per crops. It is very remarkable how Switzerland and UK have very high emissions levels related to these crops in comparison to China and India, except for the case of Soybeans.

This would indicates that a country that harvest very large areas of a given crop is more efficient. But the case of soybeans is different as we observe that the main producer is also the least efficient one regarding greenhouse gases emissions. This might be explained by the replacement of humans by machines. As explained in section III, in the USA, the ratio of machines over humans working in the fields is considerably higher than in other countries. This fact support arguments against the automation and the wide replacement of humans by machines in the fields.

A. Prediction of greenhouse gases emissions

To predict the emissions, we make linear regressions to interpolate the evolution of the emissions of each crop, based on worldwide data. The output for specific crops can be seen in figure 2.

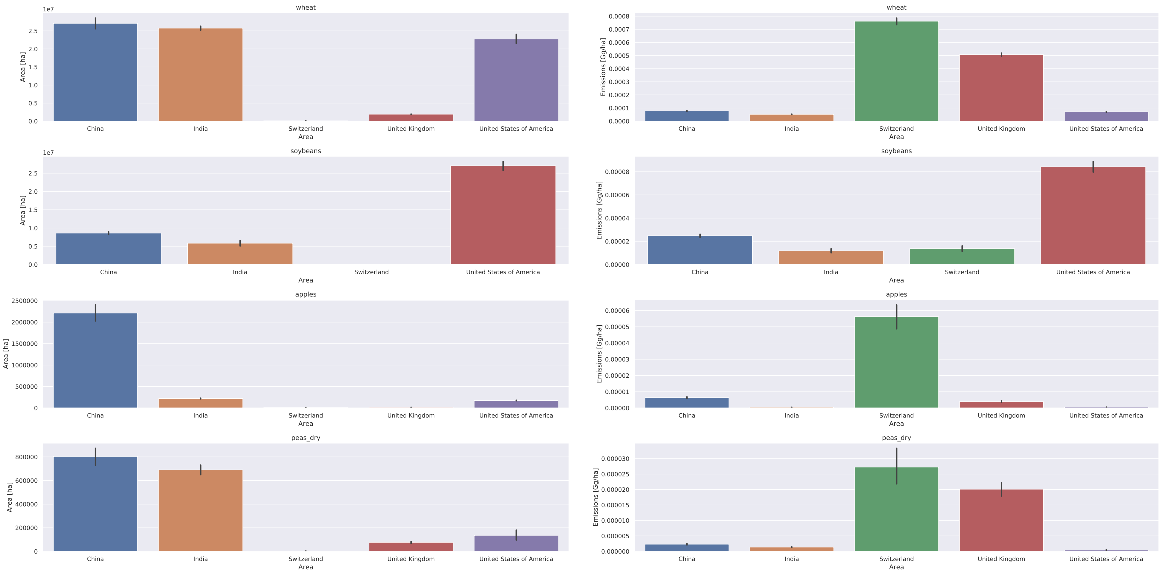

Fig. 1. On the left: Mean area harvested for each crop for a specific country over the years. On the right: Mean emissions related to each crop for a specific country.

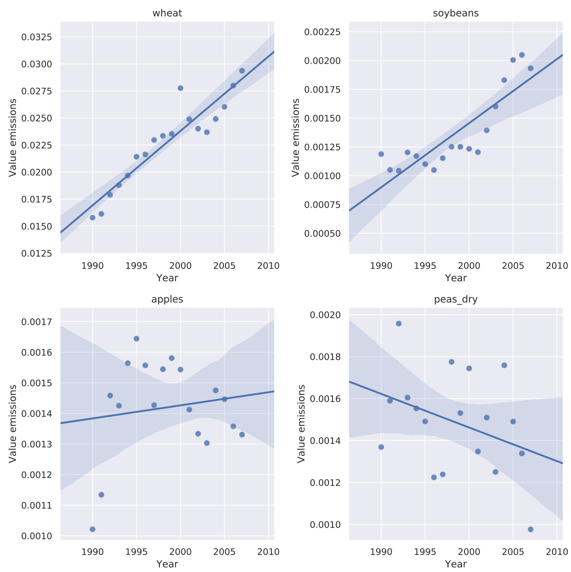

Fig. 2. Emissions per crop and linear regression as a forecasting model.

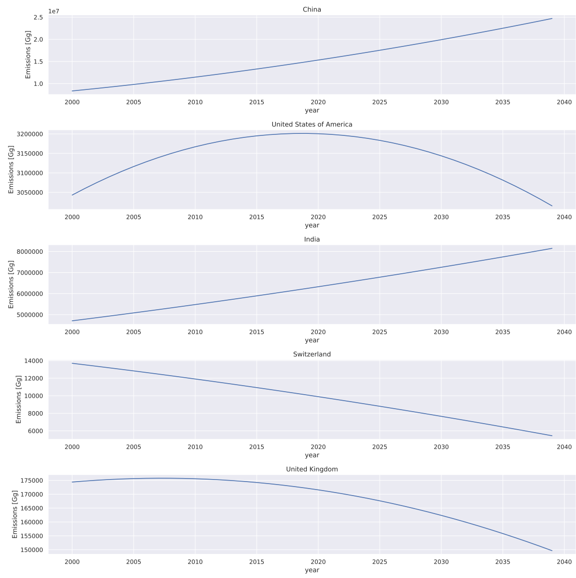

Fig. 3. Predictions of the emissions from 2000 to 2040 for the selected countries.

Some crops have a strong linear dependency while other crops can have very sparse data and a probably difficult to predict behaviour. In some cases it is very relevant to make linear regressions. For the sake of simplicity, we keep the linear regressions for all the crops.

Then, to predict the evolution of these emissions by country, we create linear regressions for each crop in each country. By using these models, we can compute the evolution of the type of agriculture in the future. Finally, by multiplying the output of each model together, we can obtain a forecast of the emissions of each country. The output of the complete model is shown in figure 3 for the selected countries.

This model shows clearly a difference between the two classes of countries: China and India on one hand and UK, USA and Switzerland on the other. The most developed countries seem to be on the right path to mitigate their emissions related to agriculture, at least based on the type of crops grown. However, China and India have dangerously increasing emissions which will inevitably worsen the climate crisis. It is still very important to recall that these predictions are only indicating that the agricultural landscape in developed countries seems to follow a good path. Nevertheless, other factors such as automation, use of chemicals or other change in the way we grow our food might have a considerable influence on its sustainability.

III. Socio-economic factors

In order to assess the social and economic impacts of agriculture we acquired new data from three different reputable sources (FAO, ILO and Databank). In order to gain precise and potentially interesting insights, we reduced our analysis to a subset of five countries (China, India, USA, Switzerland, UK). Beside our personal interest, the choice of the above countries was motivated by the following reasons:

- China: it has had a massive growth and is now world leading.
- India: it is a big country still close to its traditions and who has also seen a huge growth in the recent years.
- USA: it has always been a world power; however, it has not been growing as fast as the above countries in the recent years.
- UK: it has been a leader in Europe and has had several interesting events in the recent years such as Brexit.
- Switzerland: it is a powerful but peaceful country and has always been stable over time.

We started by looking at the evolution of agricultural lands over time for each country. However, in order to be able to compare the countries, we must normalize the raw values don't have the same scale aren't comparable. We chose to normalize by dividing the values by the total population for each country, each year. Normalizing by population makes more sense in our case: we can take the example of Greenland which has a small population and small agricultural land but has however, very large total land area.

We found out that all of the countries have a decreasing agricultural land to population ratio over time. However, USA has the highest ratio with the highest negative slope. We will discuss later some potential reasons for this result.

A major focus of our research on social factors was the employment in the agricultural field. Our acquired dataset made the distinction between male and female employment in agriculture. We investigated this separation and found rather interesting results: there is always a gap between male and female employment in agriculture. This gap decreases over time for USA, UK and Switzerland but stays rather stable for India. Comparing males and females' employment, we made an interesting discovery. We noticed that female agricultural employment stays rather stable over time but the males' employment decreases. An explanation for this observation could be the relationship of farmers of different sexes with "technology" and automatization. In fact, the major reason of the decrease in agricultural total employment could be industrialization and the automatization of agriculture using technology and machines:

- The male's labor in agriculture back in time has been gradually replaced by machines.
- Agricultural industrialization had lower impact on female's labor as they probably were not the ones harvesting the plants in the field.

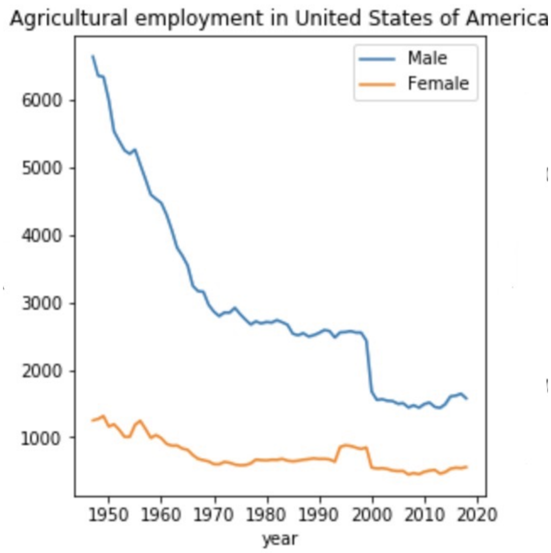

Fig. 4. USA agricultural employment

We also notice a strange downward kink in USA's chart right before year 2000 c.f fig. 4. This could be due to a big technological leap in agriculture but it is most likely due to the dot-com bubble as many people during that year converted to 'entrepreneurs' creating random websites and easily obtain funding and revenue. However, it is important to keep in mind that this is only our guess and the true reason might be completely different.

When we look at the total agricultural employment per total population ratio, we notice that all of the countries have a decreasing slope suggesting that over time there are proportionally fewer people working in the agriculture, which makes sense regarding the robotics advancements in the agricultural field. Comparing our countries of interest, China has the overall highest ratio followed by India, Switzerland, USA and UK.

The second major factor that we investigated is the economic added value that agriculture brings in for each country. We again normalized the values by the total population for each country to be able to compare them. We found that from years 2000, on average India has the largest economical added value by total population ratio, followed by China, Switzerland USA and United Kingdom. However, comparing to the agricultural land to population ratio, India has the smallest ratio. This might suggest that a person involved in agriculture in India has the least land to work with but adds more to his economy compared to the other countries. On the contrary USA has the highest agricultural land to population ratio but has the second smallest economic added value to population ratio. This might be explained by the fact that India cultivates spices which, for the same volume, are more expensive than rather traditional corn and wheat cultivated in the US.

IV. Fertilizer

Fertilizer also contribute to rising atmospheric greenhouse gas concentrations. Their production account for emissions of CO2, N2O and CH. [3] A recent paper actually state that the direct production of methane from industry in USA is underestimated by a factor 100, phenomena which could be true for others country and others nutrients production! [4]

Fertilizer not only are toxic in the air but they also pollute water as they flow with the rain and induce eutrophication. It is ”an enrichment of water by nutrient salts that causes structural changes to the ecosystem such as: increased production of algae and aquatic plants, depletion of fish species, general deterioration of water quality and other effects that reduce and preclude use”. This is one of the first definitions given to the eutrophic process by the Organization for Economic Cooperation and Development in the 70s.

Due to all this reason, uses of fertilizer should be minimized. Let’s analyse Fertilizer features from the data and see if we can optimize their use.

First of all, we can see that the use of fertilizer is increasing with time which might be consistent with countries development and demography growth.

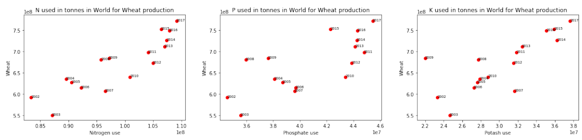

Fig. 5. Total of use Fertilizer in tons in the world for the wheat production

In this case the relation is quite linear so uses of fertilizer seem to be helpful but let’s not be biased. We should divide the production by the area harvested in order to scale result as more fertilizer could be simply related to largest field harvested. In the plot below, we show the linear regression of the total nutrient use divided by the harvest in hectare for the wheat production.

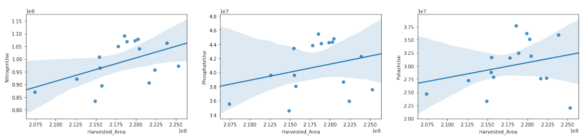

Fig. 6. Total of Fertilizer used in the world per area of field per year from 2001 to 2017. R squared value are 0.816 for the Nitrogen, 0.611 for the phosphate and 0.673 for the potassium.

The relation is still linear and positive, so in a global view it might beneficial for the farm to use a lot of fertilizer. Nevertheless, let’s look at a country which might use too much fertilizer, the USA. his R squared value for nitrogen (N), phosphate (P) and Potassium (K) regressions are 0.117, 009, 0.002. There is no relation at all! It’s mean that the field are over saturated with fertilizer. Indeed, as the same principle of a limiting reactive in a chemical reaction if nutrient are missing, they will directly influence the crop production.

An intuition we can have, is that least developing country are more regarding to avoid waste fertilizer as they can not afford it. The plot bellows shows the relation of the total of least developed countries vs the others. Indeed, they have a bigger positive linear relation.

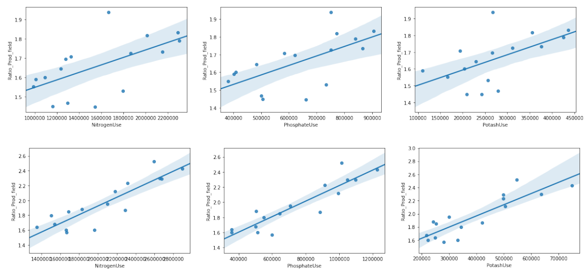

Fig. 7. Comparison of rich and least devl. countries correlation of nutrient use [tons/hectare] Least developed countries are on top. R squared are: 0.787, 0.821, 0.761, 0.363, 0.398, 0.319 for the linear regression in the order of plot layouts

Now, let use the Pearson correlations as an indirect indicator of good use of fertilizer. An high positive value reflect the appropriate use of fertilizer. In contrast, low or negative correlation induce too much utilization of fertilizer. The value were calculated for all country and item in a data sets. In case of the USA’s main crop, the table result below shows that only the nitrogen for the Seed cotton farming is not over-saturated:

USA	N_corr.	P_corr.	K_corr.
Maize	0.051	-0.072	0.085
Seed cotton	0.792	0.355	0.315
Soybeans	0.247	0.013	0.110
Wheat	0.342	-0.096	-0.040

Like in this example, the dataset of the Pearson correlation could be used to find which crop production in which country is using too much fertilizer. This target should received less of the nutrient which have a bad correlation.

References

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[4] Xiaochi Zhou et al. “Estimation of methane emissions from the US ammonia fertilizer industry using a mobile sensing approach”. In: *Elem Sci Anth* 7.1 (2019).