Agriculture Impact on Climate Change and Climate Change Impact on Agriculture - Low Power Design

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***Abstract*—The world is going into a disaster if no actions are taken soon to stop the global warming and the corresponding climate change. The agribusiness sector is responsible for almost a third of the greenhouse gas emissions (GHG). On the other hand, this sector is one of the most affected by climate change. Technology, IoT, machine learning, low power design, and artificial intelligence should play an important and essential role as it provides ways to measure and analyze data that will show GHG emissions and the main sources. From collected data, through a deep analysis, information can be sent to the farmers and some actions can be taken. In this paper we will analyze how climate change is affecting agribusiness, how agribussines is affecting climate change and how technology could help to mitigate the impact of climate change. Different options for low power design are also presented.**

***Index Terms*—IoT, climate change, smart agriculture, food security, GHG emissions, low power design, SoC**

I. Introduction

It is clear that climate change is affecting the Earth and our lives. It is also clear that it is anthropogenic, i.e. caused by humans. It has been proven that the increase of temperature is correlated with the CO_2 concentration. Three main gases are producing the climate change, carbon dioxide CO_2, Methane (CH_4), and Nitrous Oxide (N_2O).

One third of global Greenhouse Gas (GHG) emissions is caused by agriculture, forestry, and change of land usage according to Food and Agriculture Organisation of the United Nations (FAO). If those emissions are not controlled, they will increase by 15 to 20% by 2050 as population is growing as well as the need for food. 17% of nitrous oxide (N_2O) is coming from fertilized soils, 14% from biomass burning and 47% from land conversion to agriculture. Planetary boundaries defined by Johan Rockström from the Stockholm Resilience Centre in 2009 [1] are affected by the agribusiness sector, and the most affected are: climate change, nitrogen and phosphorous loading, land conversion, and biodiversity loss. A new report shows that six out of the nine planetary boundaries are already crossed [2]. Agriculture has to be controlled to be sustainable, and technology can be a major actor of this control.

Agriculture needs to be controlled and optimized in all farms around the world, however we face additional problems as according to [3] 80% (570 million) of farms worldwide are less than 2 ha and family-run. Small farmers are far from technology and they exploit their farms using the ancestral knowledge, and producing GHG emissions with no control.

Big farmers are using existing technology systems. Unfortunately those systems cannot be used by small farmers as they cannot afford the cost of them. Additionally, the lack of digital skills of small farmers make it even more complicated the deployment of the technology systems. There are two additional issues for the deployment, the lack of communication infrastructure in the countryside and the need of energy for the implementation of the systems. Energy is the main producer of CO_2 emissions according to ClimateWatchData.org

The paper is organized as follows: In section II we present an overview of climate change and the role of agriculture on climate change. In section III we present the impact of climate change in the agribusiness and food security. In section IV we present how technology can help to mitigate the effect on agriculture and how to mitigate the GHG emissions from agriculture. We give a special part to technologies used in the agribusiness systems. Low power design is also considered as energy is an important emitter of GHG. We finally close with some conclusions of the work.

II. Overview of Climate Change and the Role of Agriculture on Climate Change

To better address the climate change problem it is important to understand the carbon cycle and the role of carbon in our lives. Carbon is in the atmosphere as carbon dioxide (CO_2). Carbon is needed to regulate Hearth's temperature, and is also a key ingredient in food.

Carbon cycle is the way nature recycle carbon atoms. It describes the continuous travel of carbon from Earth to the atmosphere and vice versa. A closed environment is formed by the planet and the atmosphere. There is a constant flux of carbon between the Earth and the atmosphere. The storage of carbon is done in sinks on the earth. The main sinks are rocks, sediments, oceans, atmosphere, and living organisms. Carbon cycle is presented in figure 1.

GHG emissions have been increasing since 1950; oil, coal, and gas are the main contributors to that as it is shown in figure 2. The same Figure 2 shows also the regions that contribute the most to emissions. It is interesting to see that this phenomenon appeared in a newspaper in 1912 (see figure 3). According to the article it was already a fact that the changes in CO_2 were anthropogenic.

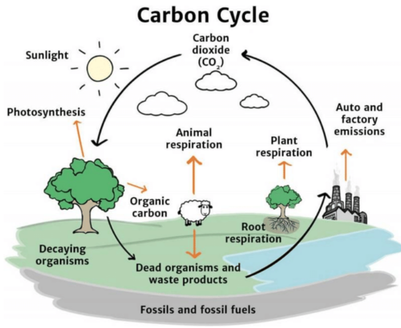


Fig. 1. Carbon Cycle

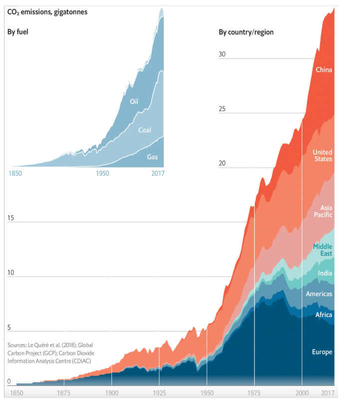
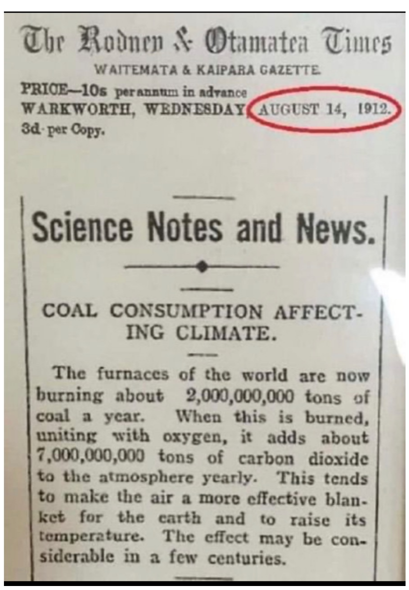


Fig. 2. CO_2 Emissions

Climate change main consequences, according to scientific studies are: sea levels, amount of rain, changes in the gulf stream, and methane release among others.

Agribusiness is responsible for one third of GHG emissions, agriculture itself is mainly responsible to methane and nitrous



The Rodney & Otamatea Times

WAITEMATA & KAIPARA GAZETTE.

PRICE—10s per annum in advance

WARKWORTH, WEDNESDAY, AUGUST 14, 1912.

3d. per Copy.

Science Notes and News.

COAL CONSUMPTION AFFECTING CLIMATE.

The furnaces of the world are now burning about 2,000,000,000 tons of coal a year. When this is burned, uniting with oxygen, it adds about 7,000,000,000 tons of carbon dioxide to the atmosphere yearly. This tends to make the air a more effective blanket for the earth and to raise its temperature. The effect may be considerable in a few centuries.

Fig. 3. Newspaper

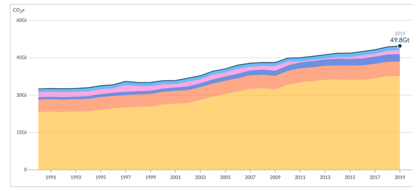


Fig. 4. Emissions per Sector

oxide emissions. The activities related to agriculture generate half of the methane emissions (mainly livestock and rice) and three quarters of nitrous oxide emissions (N_2O). Figure 4 presents the emission per sector where it is clear that agriculture and land change usage are majors emitters.

The usage of land and its conversion to agriculture is in some way a consequence of human consumption of food. FAO indicates that 29% of the surface of the Earth is land [4]. Only 71% of this surface is usable by humans, and 50% of that is used by agriculture and 37% by forests. 77% of the agricultural land is used for livestock meat and dairy, that only provides 18% of needed calories and 37% of needed proteins; the rest, 23%, is used for crops that provide 82% of the global calorie supply and 63% of the global protein supply. It is then needed a balance of land usage between livestock usage and crops usage. Poore and Nemecek indicate in [5] that 49.89 kg of CO_2 are emitted for 100 grams of beef. 100 grams of poultry meat only emit 5.7 kg. 100 grams of tomatoes emit 19 kg of CO_2, and only 1.98 for 100 grams of Tofu. A balanced diet is then also needed to reduce the GHG emissions.

The impact of food supply chain (processing, transport, packaging and retail) on GHG emissions is also analyzed by Poore and Nemecek [6]. From there it can be stated that emissions due to supply chain are equivalent or higher than emissions from land use change, on-farm, and animal feed.

United nations made a study in 2022 regarding climate change and food security. Five key takeaways for climate change, food systems, and nature loss appear in the report [7].

- *Humans have already transformed more than 70% of the Earth's land area:* Because of that the population of mammals, birds, amphibians, reptiles and fish declined by 68% between 1970 and 2016. This is due mainly to the conversion of grasslands, savannahs, forests, and wetlands to agriculture.
- *Food systems are responsible for 80% of deforestation, 29% of greenhouse gas emissions and are the single largest cause of biodiversity loss on land:* At least 40% of land surface is devoted to agriculture and half of it is degraded. Agriculture is responsible for almost 80% of deforestation as more food is needed, however if the increase in food productivity is not done in a sustainable way, soil degradation will continue to increase.
- *Protecting and restoring ecosystems could provide more than a third of the land-based climate action needed to meet global warming goals:* This simple action could re-

duce emissions and sequester carbon. Because of climate change produced by humans, many forests and grasslands are more susceptible to pests and diseases.
- *Land degradation threatens marginalized communities the most – but these groups have much to contribute to ecosystem restoration and protection:* At least 3 billion people are living nowadays with the effects of desertification, land degradation and drought. This mainly affects poor rural communities, small farmers, women, youth, indigenous peoples and other at-risk groups.
- *The world faces a stark choice between protecting and restoring land and 'business as usual':* The humanity has to chose between saving the planet or continue doing the same.

III. Impact of Climate Change on the Agribusiness and Food Security

Climate change impacts negatively Food Security, that was defined in 1996 at the World Food Summit [8]. It has the potential to reduce and even stop the advances the humanity already did reducing poverty. Climate change is likely to affect the health and productivity of crops, livestock, fish, and forests, affecting rural livehoods. Climate change affects food security in four dimensions:

- *Availability*: Loss in food production
- *Access*: Damaged infrastructures (e.g. roads)
- *Stability*: Pressure on food process increasing the dependency on food imports and food aid
- *Utilization*: Nutrition and health risks

In the rest of this section the impact of climate change on crops, livestock, and fisheries is analyzed.

Crops: Productivity and health of crops depend on the temperature, specific per specie. An increase on temperature reduces the yield of the soil. High levels of CO_2 reduce the protein and nitrogen content of certain crops, so the quality decreases. High levels of CO_2 also increase weeds, pests, and fungi. It has been demonstrated that climate change reduces the nutritional value of crops.

Livestock: Heat waves are happening more and more nowadays. It impacts the development of the livestock. Heat stress animals and affects their immunity. It reduces their fertility and milk production. Heat increases parasites ad diseases on animals. Droughts are increasing decreasing the production of food for animals.

Fisheries: Migration of species to colder regions is a consequence of climate change. The change in temperature affects breeding and migration cycles. Climate change increases the acidification of oceans weakening shellfish shells. Acidification produced by climate change modifies the marine ecosystems structures.

COP 27 ([9], November 6th to 18th, 2022 in Sharm El-Sheikh, Egypt, produced some remarks and comments regarding agriculture and agribusiness:

- Most of the carbon stocks in croplands and grasslands are in below ground plant organic matter and soil, so carbon accumulation at these sites has a mitigation potential of between 0.4 and 8.6 gigatons of CO2 per year.
- The agricultural productivity declined by 21% compared to a scenario free of climate change. It is due to factors such as high temperatures and extreme precipitation, or high levels of carbon dioxide, which reduce soil quality.
- Droughts are responsible for 80% of losses in the primary sector worldwide, according to the UN Food and Agriculture Organization (FAO).
- Agriculture accounts for 22% of all damage caused by natural disasters in developing countries.
- Smallholder farmers, the most vulnerable to climate change, account for 95% of farms and produce almost 80% of the world's food.
- UN estimates that 828 million people were going hungry in the world in 2021 and, according to the latest report on food crises, more than 205 million people are suffering from a high degree of food insecurity in 2022.

IV. Agriculture GHG Emissions Mitigation and Agribusiness Impact Mitigation

A. The Role of Agribusiness on Climate Change

Nowadays agribusiness has a dilemma: *How to increase productivity in a sustainable way?* World population has already passed 8 billions and continue to grow. According to FAO food production should increase by 70% by 2050. There are several technologies aiming the increase of soil productivity however they are probably not sustainable and they are not low power. Several systems existing nowadays are not taking care of GHG emissions, they are just looking for the increase on productivity. IoT could be a very helpful tool for the agribusiness sector and probably a key technology. Atta presented several usages of IoT in agribusiness in [11]. They are more or less sustainable and climate change aware. Agribusiness is a very large sector, and in this paper we want just to address a few topics such as irrigation, change of land usage, fertilization, use of pesticides, and weed removal products. We also cover low power design because the importance of reducing the energy consumed by agribusiness systems.

Irrigation: Agriculture is one of the most important consumer of freshwater, agriculture uses almost 70% of the blue water withdrawals from watercourse and ground water. As water is becoming a limited resource, it is important to reduce the amount of water used by agriculture. The amount of needed water per crop does not only depend on soil humidity, it is also important to measure other parameters such as the specie, the type of soil, salinity, and pH. Grimblatt et al. [10] analyze some of the parameters that have to be measured for optimal irrigation. Each specie has a specific watering threshold and it s easy to find it on agronomy books and papers. Being able to calculate how close is the plant to the threshold based on measurement will save a lot of water.

Change of Land Usage: Large areas are being converted to agribusiness, especially forests, to be used on livestock. Sometimes this is even illegal and it is done through wildfires produced by humans. Detecting and alerting wildfires is a way to manage the destruction of the forest. Cameras, sensors, and IoT can be used for that purpose.

Fertilization: Crops need nutrients. Nutrients can be non mineral (Hydrogen, Oxygen, and carbon) and minerals (Nitrogen, Phosphorous, Potassium, Calcium, Magnesium, Sulfur, Boron, Copper, Chloride, Manganese, Molybdenum, and Zinc). Among these nutrients the most important are Nitrogen, Phosphorous, and Potassium (NPK). In general fertilization is done without measuring what is needed, which depend on the specie. Over and under fertilization impact negatively the crop and the land, so being able to measure the available nutrients on the soil is needed, however nowadays this measurement can only be done through a soil sample sent to a laboratory, which is not done by small farmers. Today there is no low cost and in-situ system to measure nutrients.

Use of Pesticides: Pesticides are applied by farmers in order to prevent any consequence on the production because of pests. In general, small and medium farmers apply these pesticides without any measurement on where and the quantity they need to apply. Having more information through measurement will allow farmers to do an accurate and safer application of pesticides, protecting other species and pollination animals such as bees.

Weed Removal Products: In the same way, small and medium farmers apply weed removal products without measuring where and how much they need. Visual analysis of land could optimize the usage of these products reducing their impact on the land and environment.

B. The Role of Technology

Different technologies can be used to be able to mitigate the impact of agriculture on climate change. G. Sucharita and M. Mandeep Sai make a very good analysis about the usage of IoT in agriculture in [12]. There are several existing applications of IoT for the agribusiness covering almost all domains. From monitoring crops and livestock to production of food, IoT is present and help farmers to improve their productivity. IoT in agribusiness depends on the availability of sensors that are able to produce the requested data to be processed. As almost 80% of farmers have less than 2 ha., it is necessary to have low cost sensors, which is not always the case. Marios Sophocleous et al. present in [13] a sensor that is able to capture several soil parameters aiming to be able to analyze the quality of the soil. Processing this data, the specie of the crops and the type of soil will allow us to improve the productivity of the soil. Grimblatt presented in [14] an overview of IoT for agribusiness.

But not only the soil can be measured to provide information about the growth conditions for a specific crop, Stefano Calvo et al. present in [15] a system that monitors the plant water stress status trough the monitoring of the trunk electrical impedance. Combining soil sensors and trunk impedance sensors could also help on the monitoring of the health of the plant.

Artificial intelligence is also being applied on agribusiness to cover different requests coming from users. Crop detection using neural networks, diseases detection, contaminants in food detection, water stress detection, mushroom detection in natural environment are some of the applications that were presented at the 1st IEEE Conference on Agrifood Electronics (CAFE - Torino, Italy, September 25-27, 2023). Unfortunately the proceedings are not yet at IEEE Xplore at the time this paper is being presented, so papers cannot be properly referenced.

Communication systems to transfer the data captured by the sensors is another issue that agribusiness systems face as the common networks are not always present in the field. LoRa [16] is used by the majority of agribusiness applications because it can transfer data over long distances easily and cost-effectively. Several papers has been published on the LoRa usage in agribusiness like [17], [18], and [19] among others.

Transfer data to be processed in the cloud or the fog is power expensive, so we are seeing more and more systems that are based on edge computing and process data locally and transfer the processed data one or twice a day. Jaime Lloret present the edge computing in agriculture in [20]. Pranjal Joshi et al. present an application, FarmEdge [21], to enable digital agriculture.

Grimblatt et al. proposed a specific SoC for agricultural applications in [22]. In this work low power design is considered a must for agricultural applications as in general the systems are far from the energy sources. Low power can be achieved in several ways on SoC design. The most important technologies for low power of digital systems are

- *Clock Gating*: Technique used to reduce dynamic power through disabling the clock signal when the output of a register is not changing on a clock edge.
- *Multivoltage*: Technique used to reduce dynamic and static power by having different power supplies on an integrated circuit.
- *Power gating*: Technique used to reduce dynamic and static power power through shutting off a block of the circuit.
- *A combination of above technologies*

V. Conclusion

Agriculture, forestry, and change of land usage are one of the majors produces of GHG emissions (at least one third); agribusiness is an affected sectors by the climate change. Additionally, more food will be needed according to the growth of the population and estimations are expecting a 70% increase in agriculture production by 2050. The agriculture dilemma is how to increase productivity in a sustainable way so GHG emissions are not increased, even more how to reduce them. Technology can be the answer to this dilemma. We presented in this paper the situation on climate change and agriculture and we mention some solutions that can be applied. The role of technology is also presented analyzing the usage of IoT, artificial intelligence, LoRa, edge computing, and low power design. A lot of work has been done by researchers in the agribusiness domain, however it is necessary to adapt our researchs to the environment and economic conditions of the sector.

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