Climate Change, Food Security and Agriculture, a term-based correlation analysis

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Abstract. *This conference paper is an introductory study on the relationship and the nature of the linkage between climate change, agriculture and food security as seen across three different perspectives. The first perspective is the definition of food security and how it related to climate change and agricultural activities, the second perspective is the definition of agricultural activities and how are they linked with climate and food production/consumption and the third perspective of climate change and how it is contributing to the risk assessment studies conducted to evaluate and improve food security and enhance agricultural activity by utilizing sustainable methods and environmentally friendly practices.*
The study has been undertaken to fulfill the research scope. Conclusions closed with listing the importance and the impacts of climatic changes, agricultural practices and resilient food security measurements

Keywords: climate change, food security, agriculture, term analysis

Introduction

According to United Nations 2015 report about the state of food security; 800 million people are hungry and around 2 billion does not have access to quality and nutrient food – this reflects the nature of the problem and poses questions that should be tackled by international entities as well as governments and global political economy policy that reconsiders the different universal conditions that help authorities to facilitate different strategies to bridge the gap between supply and demand for "healthy" food across nations.

The importance of the research is based on substantial literature that explores the roots of the relation between climate change, food security/insecurity and the agriculture / agri-tech and agribusiness, and the focus is on:

- Formulating the nature of the relation to understand the impacts of the selected variables on the overall macroeconomic and microeconomic indicators – especially for policy makers, governments, and stakeholders.
- Synthesizing creative resolutions to reduce negative impacts and convert threats and weaknesses to new opportunities that will add value and promote sustainability.
- Understanding the impacts of climate change on agriculture and food security and trying to find new ways to reduce global warming that hurts directly crops, fisheries and rural economies.

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The climate challenges as defined by the Intergovernmental Panel on Climate Change (IPCC) are highlighting these issues:

- Loss of rural livelihood and income: The direct impact on rural areas is the destruction of these areas due to climatic disasters – followed by dramatic reductions in household incomes and rural employment.
- Loss of marine and coastal ecosystems and livelihood at this level due to drastic climatic change that usually follows droughts, floods and level changes in the sea caused by the melting of Arctic ice.
- Loss of terrestrial and inland water ecosystems and livelihoods caused by increased temperatures, the direct impacts of change in soil structure and the variations in rainfalls precipitations.
- Food insecurity and breakdown of food system deteriorated by drastic changes in supply food chains rerouted to catastrophic climate changes and extreme climatic phenomenon.

FAO's study on a sample of 78 post-disaster needs assessed in 48 developing countries revealed that between 2003 and 2013 around 25% of economic loss and damage was caused by medium and large-scale climatic disasters such as floods, storms, and drought in the agricultural sector. The relation and the nature of the effect is direct, impactful, highly correlated and causing irreversible damage to agricultural production and the agro-food sector (supply and demand).

The impacts of climate changes on food security and agricultural activities can be summarized into:

Direct impacts:

- Changes in the way of conducting agricultural activities in different geographic locations happening simultaneously with technological changes;
- Changes in the production system impacting economic and social activities, originating as a new form of land ownership, varying investment strategies and international trade activities;
- Imbalance the optimization of access, availability, utility and stability of food security by rapidly changing the conditions for agriculture, aquaculture, apiculture and other food/water production natural processes.

Indirect impacts:

- Social and cultural regional relations as well as global and universal perspectives on what is indigenous;
- Consumerism and the changing habits of buyers and sellers.

The research is conducted using existing secondary data and literature that highlights the nature of the relation as seen from different perspectives. Collecting literature that addresses mainly the following variables: climate change, food security and agriculture.

The objectives of the study are to: examine the relationship between climate change, food security and agriculture, add value and insights for policy makers to help in shaping different macroeconomic and microeconomic policies and bridge sustainability, food security and agriculture.

Literature review

In the last years, agriculture has been confronted with a lot of problems which raised the natural system vulnerability who reply through extreme events. Wildfires ravage Siberia and Amazonia in 2019; Australia was devasted by the fire in 2020, Greece and Turkey and California in 2021; floods in China in 2020; strongest tropical cyclone in the Philippines are just a few issues caused by climate changes. In agriculture, the rising usage of pesticides is a serious health problem related to agricultural intensification. The EU policies set up the sustainable use of pesticides by reducing the risks and impacts of pesticide use on human health and the environment, as well as promoting the use of integrated pest management and alternative methods or procedures, such as non-chemical pesticide alternatives (Iriti, 2020).

Climate change continues to have an influence on the water systems, including effects on water quantity and quality. Changes due to melting glaciers, changing seasonal precipitation, raising river flows and continuing to increase underground water contributions to these flows, thawing permafrost affecting groundwater flow into streams and rivers, and increasing evapotranspiration are examples of climate change impacts on water quantity. Such climate change risks to drinking water are aggravated by existing water treatment infrastructure problems pertaining to extremely cold environments, remote and rural areas of many communities, often smaller population sizes than southern locales, and frequently lack of resources. As a result, in many settlements in the Circumpolar North, surface water is treated to rudimentary standard treatment before being piped under- or above-ground to buildings or trucked there (Harper et al., 2020).

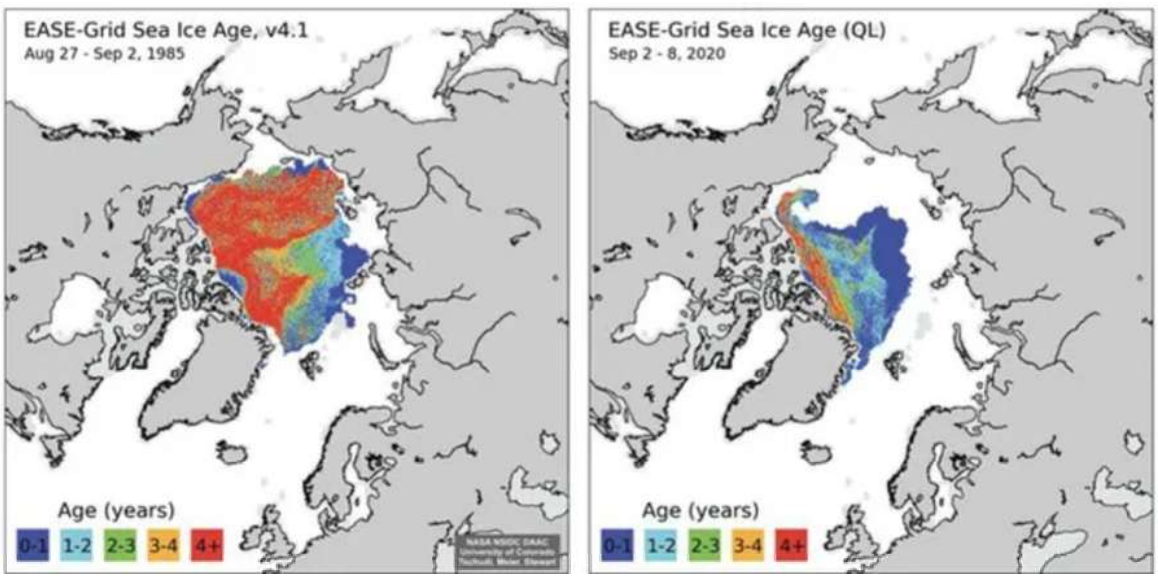

Figure 1. Arctic Sea Ice Age

Source: (NSIDC, 2020).

On September 15, 2020, Arctic sea ice hit its annual minimum, reaching its second-lowest extent and volume ever recorded, trailing only 2012. According to the recent research, despite rising temperatures, the 2012 record has not been surpassed because the fast-warming Arctic has disrupted the jet stream, resulting in foggy summer Arctic conditions that have temporarily preserved some sea ice. Long-term climate change, therefore, will ultimately dominate, and experts predict that the Arctic will be ice-free in the summer between 2030 and 2050. Over the last 40 years, three-quarters of the Arctic's summer sea ice has gone (Nuccitelli, 2020).

Due to climate change, agriculture is affected in a variety of ways and intensities, with farmers' ability to respond varies. Sometimes consequences are fast and severe, referred to by climate scientists as shocks, and they frequently result in large-scale crop failures, resulting in thousands of deaths and displaced people. To adapt to shocks means, in the first-row difficulty: regional and worldwide action is required to reduce carbon emissions in order to potentially minimize warming and, as a result, the occurrence of such extremes in the first instance (Ires, 2021).

Organic agriculture offers a large potential area, both in terms of land expansion under organically cultivated products and the extra value that these products generate. Since 1999, there has been a steady increase in organic production. In 2018, the area under organic farming was estimated to be 11,000,000 hectares, out of a total of 71,514,580 hectares (Vuckovski and Kovacevic, 2020).

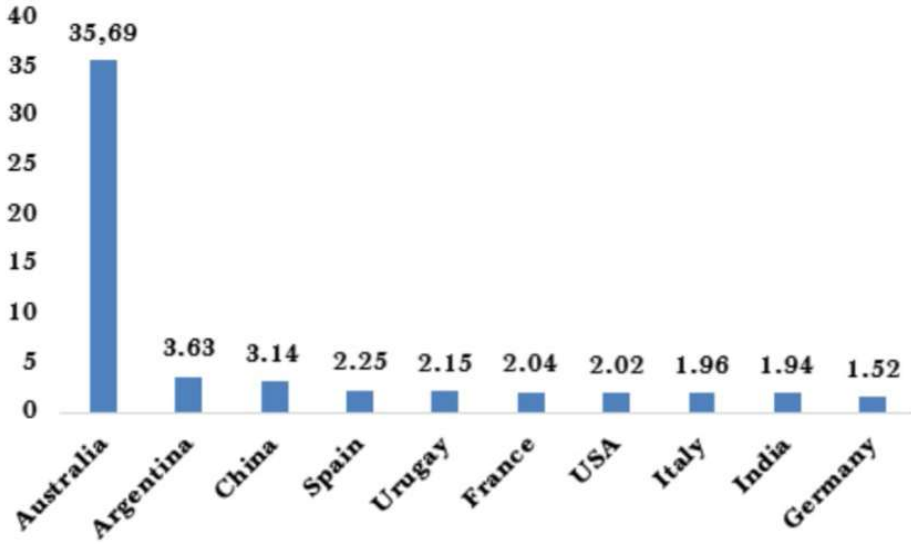

Figure 2. Countries with the largest organic agricultural land in 2018 (million hectares)

Source: Willer et al., 2020.

IFOAM (2008) defines organic agriculture as ”a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic Agriculture combines tradition, innovation, and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved.”

Since the pre-industrial era, anthropogenic GES emissions have risen, owing mostly to economic and population expansion. Emissions were at an all-time high from 2000 to 2010. Historical emissions have resulted in record quantities in the atmosphere in at least the last 800,000 years, resulting in an energy intake by the climate system. The data is showing human contribution to the climate system is becoming more compelling. Warming of the atmosphere and oceans, changes in the global water cycle, decreases in snow and ice, and global mean sea level rise have all been linked to human activity, and it is very likely that human activity has been the primary cause of the observed warming since the mid-20th century. Climate change has had an influence on natural and human systems on all continents and across seas in recent decades. Impacts are a result of observable climate change, regardless of its origin, illustrating the vulnerability of natural and human systems to climate change (IPCC, 2015).

The agricultural industry is, by definition, vulnerable to climatological change, and global warming has already produced and will continue to create issues for production across the board. Water shortages, drought, irregular precipitation, groundwater depletion, and increased pesticide assault are all projected to be important issues in the future for all agricultural sectors.

As a consequence, the lack of sustainability concern in adapted local adaptation practices can be exacerbated by the local community's inability to consider sustainability, which is an avowedly long-run consideration that collides with the need to secure short-term livelihood, as well as the lack of government entities willing to delegate decision power to local community members, and the side effects that delegative decision processes entail (Ahsan et al., 2021).

Agriculture adaptation to climate change is critical for assessing effect and susceptibility, as well as developing climate change policy. A wide range of adaptation techniques have been presented as having the potential to minimize agricultural system sensitivity to climate change hazards, frequently on an ad hoc basis (Smit and Skinner, 2002).

The circular economy (CE) is a promising strategy for supporting sustainable, restorative, and regenerative agriculture in the actual context of resource constraints, global climate change, environmental degradation, and rising food demand. Agriculture is responsible for more than 90% of terrestrial and water-related environmental implications, such as water stress and habitat loss. As a result, further investigation is necessary to explore strategies to increase agricultural production's resource efficiency and sustainability by implementing CE strategies. It is critical to understand how the CE may be applied in agricultural systems and what categories of indicators can be used to qualify success in the whole process.

Transitioning from a linear to a CE model is now a challenge that requires the expansion and the use of new knowledge, resulting in creative, technologically advanced, and long-lasting processes, goods, and services. (Velasco-Munoz, 2021).

Climate change will have an impact on people's capacity to purchase food, mostly through buying. The majority of the effort on access is concerned with food supply availability. Systems of interconnected climate, agricultural, and market mechanisms can be used to predict farm products prices and trade into the future under various global warming and socioeconomic conditions, with the findings used to infer consequences on food affordability for specific populations. Macro-level effects of climate change on future accessibility: food prices are expected to rise over a broader range of scenarios, although there are significant discrepancies in the outcomes of different macro-economic models. Before this between-model the lack of certainty is minimized, economic model ensemble assessments may be required. Household purchasing power, which is influenced by climate change, is also a factor, especially among agricultural households (Campell et al., 2016).

As growing population is directly increasing the interdependency of climate change, food security and agriculture, further negative effects are predictable for the environment and in order to diminish their footprint the produced food needs better optimization to achieve efficiency and larger quantities spread more uniformly (Godfray et al., 2010).

The fact that agriculture negatively impacts the environment as presented by Tilman et al., (2001) should signal the need for global alignment on implementing a mitigation plan.

Methodology

The main objective of the current analysis is to highlight the key concepts that result from the Climate Change, Food Security and Agriculture term merge and to determine what the scientific community is concentrating on.

The current analysis has taken into consideration the general aspects of these three concepts and pointed out interlinkages and convergence points. In the following part, using consecrated research methods such as the one of bibliometrics, several quantitative measurements have been undertaken to fulfill the research scope. The data used below has been obtained from two prominent international abstract & citation databases: Web of Science (WoS) and Scopus (SC). Both interrogations have been performed using the “climate change” AND “food security” AND “agriculture” filters within the Title and Abstract fields of identifiable papers.

Results and discussions

In WoS there have been identified 2992 papers whilst in SC 3207 papers compose our population.

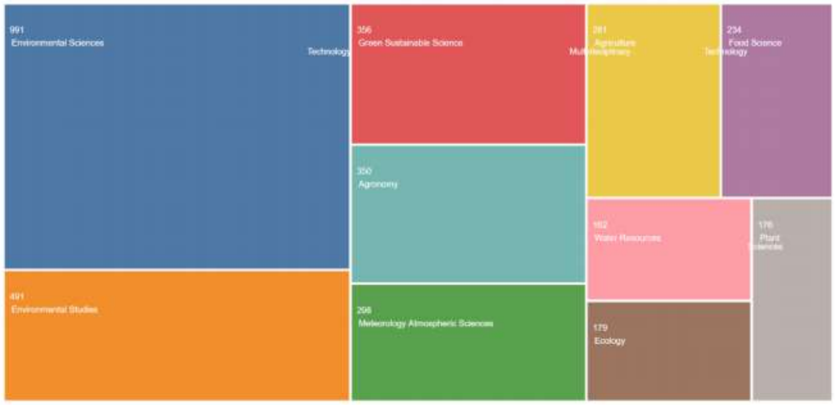

Figure 3. Interrogation results for "climate change" AND "food security" AND "agriculture" keywords by WoS theme

Source: Web of Science – Clarivate.

In the above figure, the research papers have been integrated into several research topics, almost half of the database is integrated into the Environmental Sciences & Studies topic (1482 papers or 49%), the remaining half belonging to Agriculture, Meteorology and Food related topics.

Figure 4. Interrogation results for "climate change" AND "food security" AND "agriculture" keywords by Country of origin

Source: Web of Science – Clarivate.

In order to ensure the international focus on the 3 subjects, the publishing entities belong to the USA (26%), UK (13%), China (12%), Germany (10%), Australia (10%) and India (9%); all the consecrated research poles overviewing these up-to-date scientific topics.

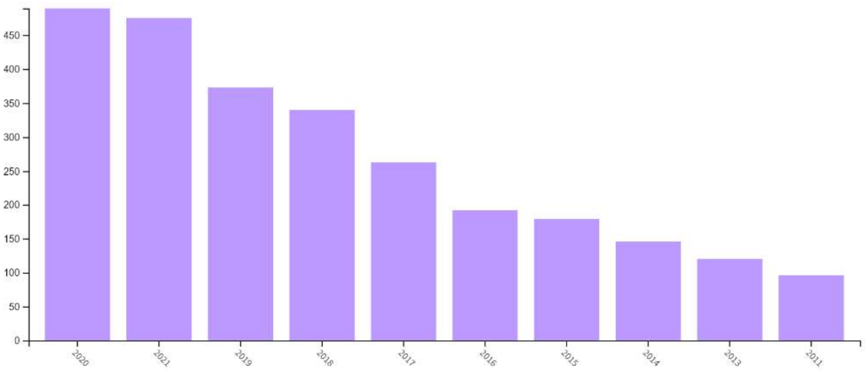

Figure 5. Interrogation results for "climate change" AND "food security" AND "agriculture" keywords by Year of publication

Source: Web of Science – Clarivate.

As presented above, year 2020 marks the greatest number of papers, almost 500 of them while 2021 shortly coming after with 480 papers. What is to be observed is the research interest for these topics that has exponentially increased since 2015 matching with the Agenda 2030 launch.

In the following part, term-correlation bibliometric maps will be drawn with the aid of VOSviewer software, that is primarily considering relevance scores and term occurrences that has met the threshold of minimum 10 appearances within the title and abstract. Same approach is considered for both databases, and the following dual analysis comes to point out similitudes and cluster uniqueness.

For the WOS model, the dataset extract has been rendered for the Title and abstract fields, method of counting: binary counting, and out of the 17296 identified terms, 555 met the minimum 10 appearances mentioned earlier, out of the 555 terms, based on the resulting relevance score (as a link strength and number of appearances in multiple papers) only the first 60% most relevant terms have been taken into consideration as software standard.

For the SC model, the dataset extract has been rendered for the Title and abstract fields, method of counting: binary counting, and out of the 38874 identified terms, 1299 met the minimum 10 appearances mentioned earlier, out of the 1299 terms, based on the resulting relevance score (as a link strength and number of appearances in multiple papers) only the first 60% most relevant terms have been taken into consideration as software standard.

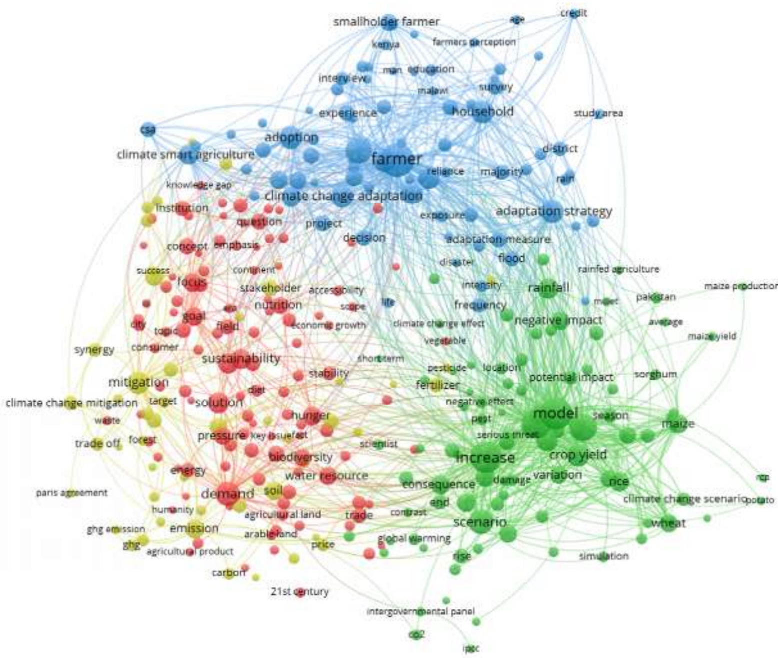

Figure 6. Word cluster map based on "climate change" AND "food security" AND "agriculture" WoS interrogation

Source: Processed by the authors in VOSviewer.

The first map rendered, presented above, from the WoS database clearly distinguishes the three main topics of climate change, food security and agriculture. The first cluster identified above is the one in blue that correlates terms from the agricultural area, "farmer" being the representative term, that will be separately analyzed together with the "model" term of the green cluster and the "sustainability" term of the red cluster. The farmer cluster is the most exhaustive cluster that encapsulates the need for a climate-smart agriculture, the role of individual households and small farmers, that points towards an adaptive project-based industry growth. The green cluster identified with the climate change topic, signals possible trade-offs for higher yields manifested through the negative effects towards rainfall, location and increasing uncertainty. The third word cluster, the one matching with food security that is in red, shows the focus toward identifying a solution for the increasing population, that generates higher food demand in order to fulfill hunger diminishment, actions that tremble the stability of water resources and biodiversity.

What's important to observe besides the three main clusters is the fourth one highlighted in yellow, one that incorporates all the three main terms from other clusters, basically confirming that to obtain diminishing negative climate impact of an inclusive agriculture, there is an acute implementation need of green synergic initiatives.

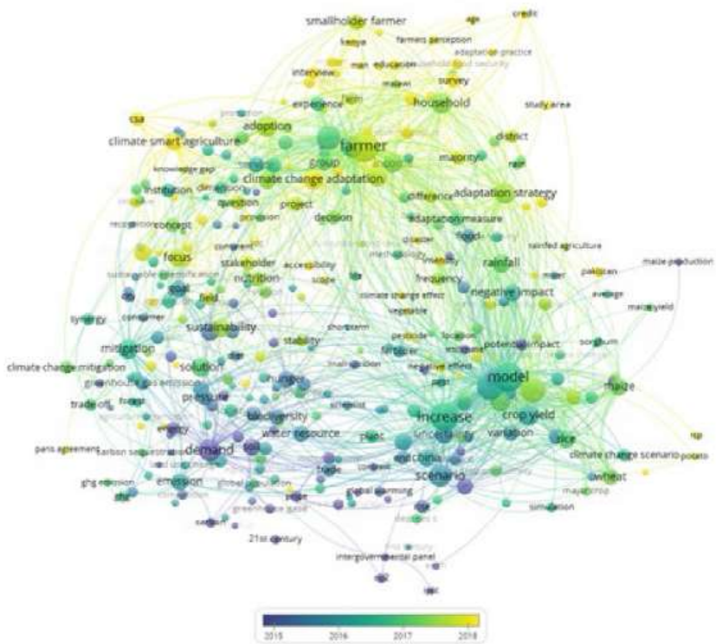

Figure 7. Word cluster map based on "climate change" AND "food security" AND "agriculture" WoS interrogation by year of publication

Source: Processed by the authors in VOSviewer.

The second map reveals the interest timeframe in research literature, with terms dating back from 2015 such as demand, food price, energy and soil (all present in the initial red cluster), early 2017 that includes mixed cluster terms, but the majority of terms come from the climate change cluster such as rainfall, climate change, shift, rice and peripheral cluster terms such as livelihood, mitigation and solution; past 2018, the agricultural cluster (previously in blue) with terms including: climate change adaptation, education, survey and climate-smart agriculture.

Recent local focus towards communities and individuals can be observable across the top yellowish terms in opposition with the market related focus that started in early 2015 in dark blue, signaling a scientific changing orientation from broader policies to locally tailored solutions.

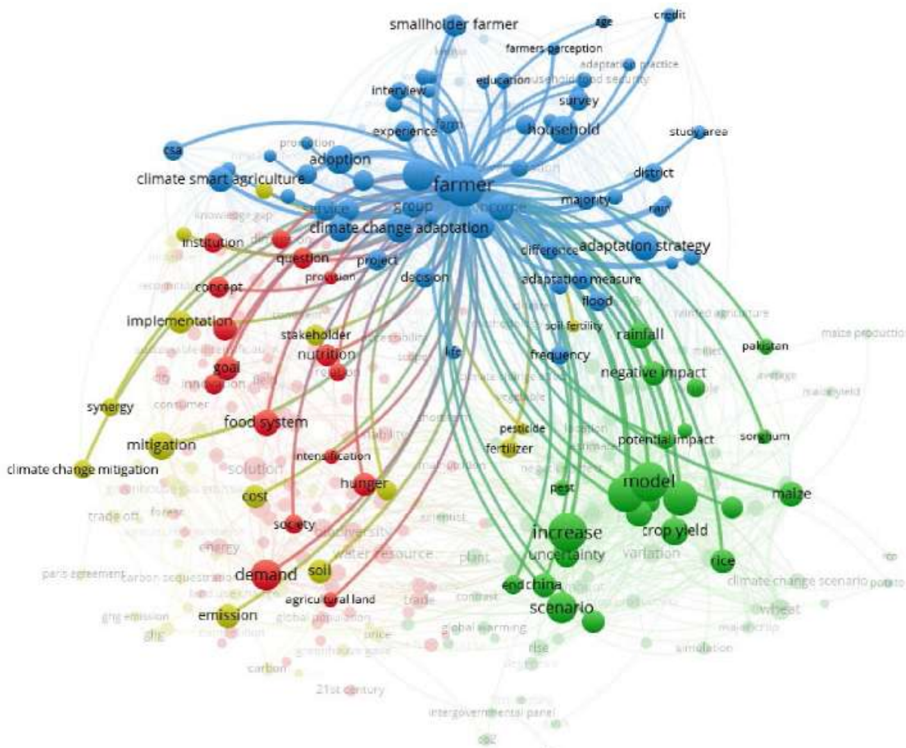

Figure 8. Word cluster map based on “climate change” AND “food security” AND “agriculture” WoS interrogation – first cluster “farmer” relating to agriculture and its relationships

Source: Processed by the authors in VOSviewer.

The first identified cluster in blue is presented above with its outsider connections, across all clusters, clearly signaling how inter-related are the three topics of the study; incorporating even terms from the yellow cluster, revealing the expected link between agriculture and climate change, also incorporating how agriculture is influencing food security.

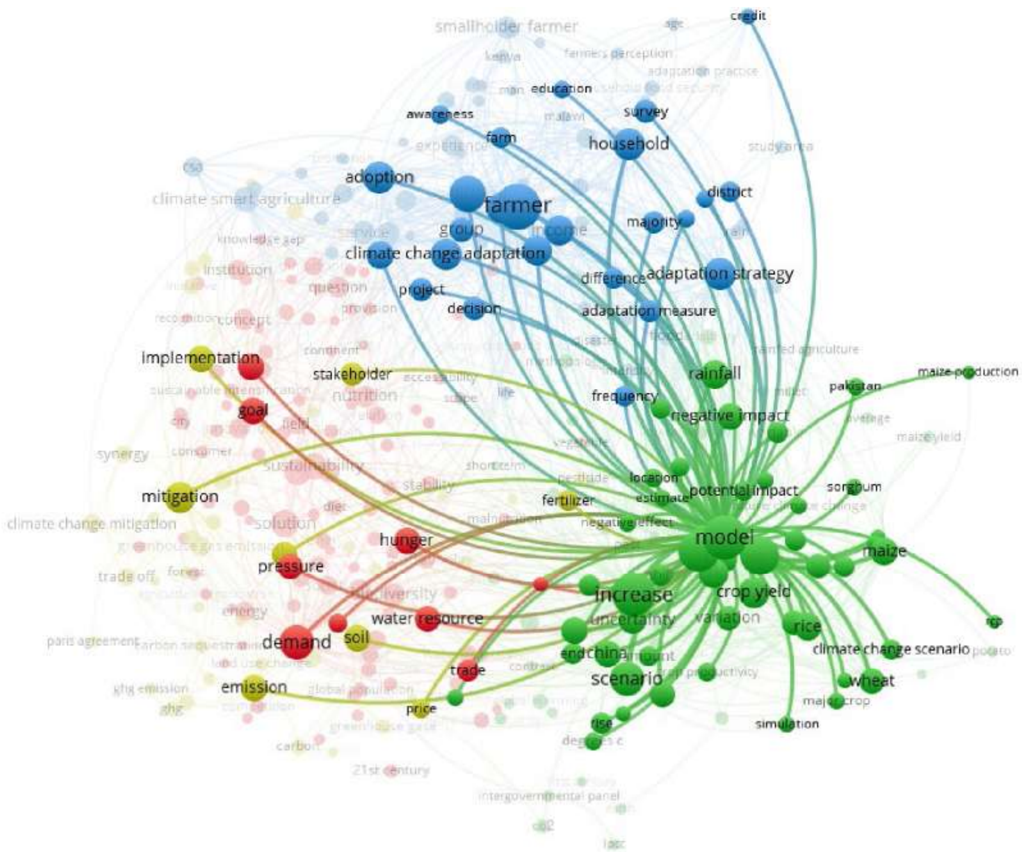

Figure 9. Word cluster map based on "climate change" AND "food security" AND "agriculture" WoS interrogation – second cluster "model" relating to climate change and its relationships

Source: Processed by the authors in VOSviewer.

The second cluster in green, presented in the above map together with main term links reveal and reinforce the interdependency to the agricultural cluster. How one influence the other does not represent the objective of the study but could represent a future study objective. One indication is already noted within the terms of existing studies, the one of negative impact and the need of adaptation across both measures and strategies.

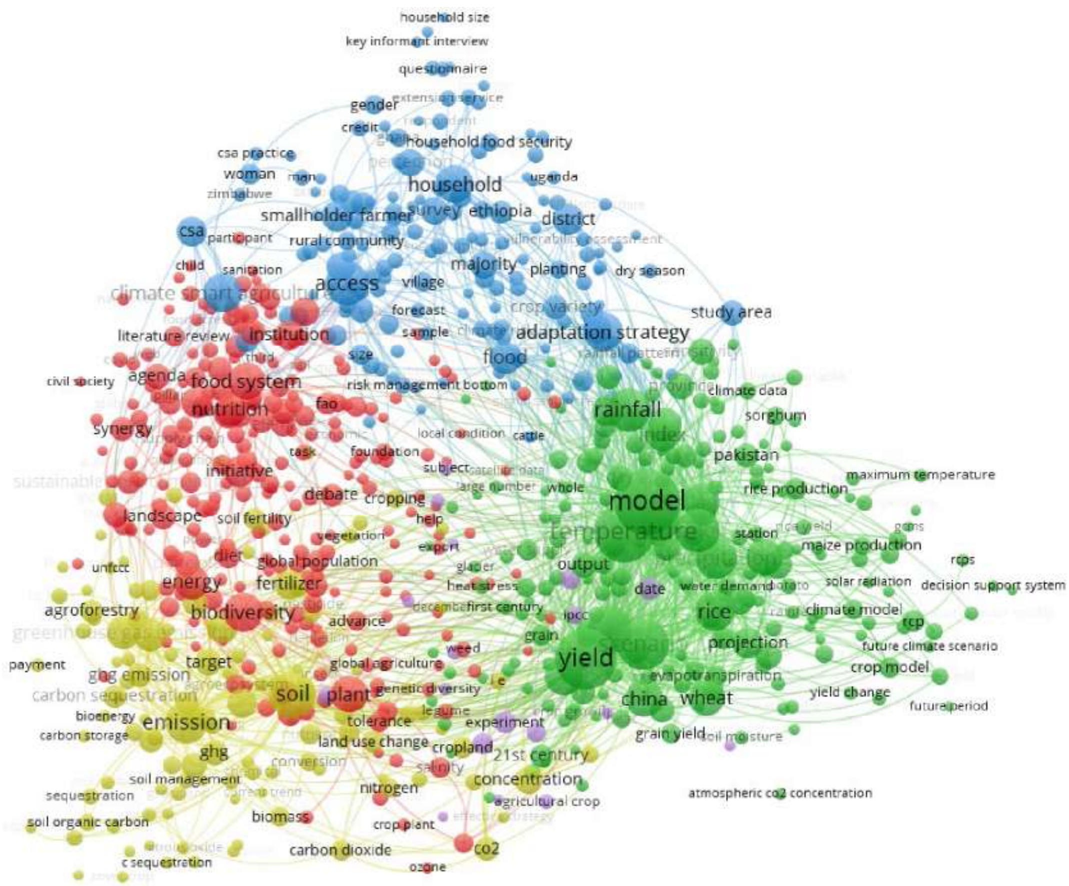

Figure 10. Word cluster map based on “climate change” AND “food security” AND “agriculture” SC interrogation

Source: Processed by the authors in VOSviewer.

The first model drawn based on the Scopus database is presenting a broader term legend, similar clusters to WoS are identified, in fact all the four previously identified word clusters are present in this structure as well but the yellow one is more visible and, additionally there is also a fifth mini word cluster, highlighted in purple, that’s bringing the human activity, global scale, population increase, land fragmentation and other interesting research points on the table, fact that determines the regional scalability of the three main study keywords’ interlinkage.

The first cluster in blue, presents almost identical structure with the WoS blueish word cloud that’s why a separate analysis of this one would not be performed in the following paragraphs, whereas the other main clusters would be closely overseen.

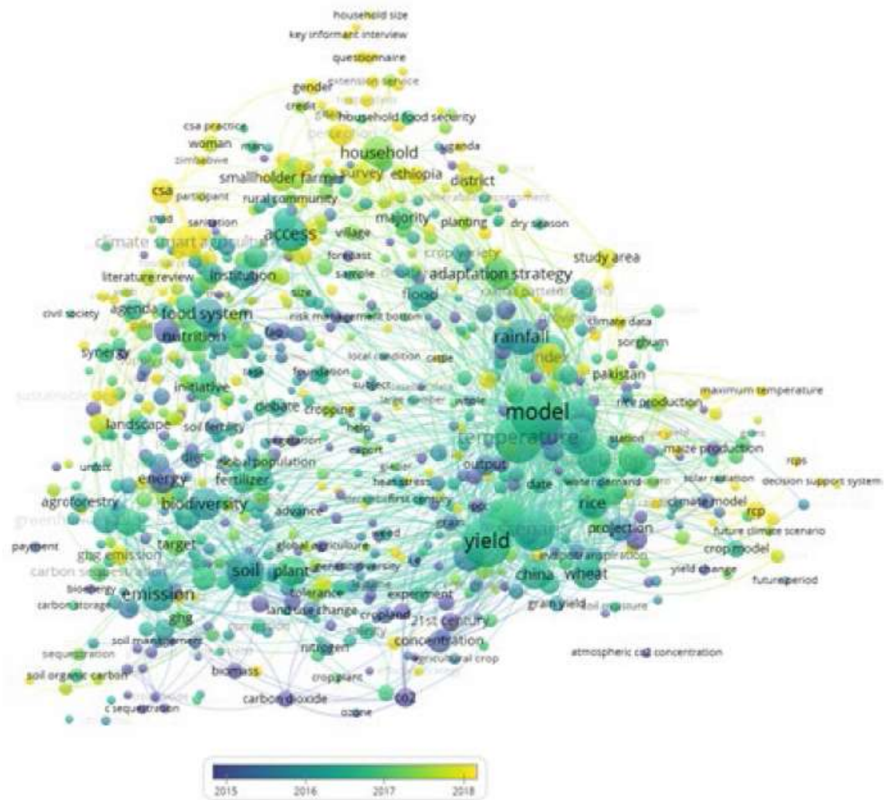

Figure 11. Word cluster map based on "climate change" AND "food security" AND "agriculture" SC interrogation by year of publication

Source: Processed by the authors in VOSviewer.

In terms of the keyword's timeframe, in the above figure, the predominant nuance stays greenish, indicating the abundance of research papers around years 2016-2017. The oldest related terms correspond back before 2015, in dark blue-purple, with simulation, intergovernmental panel, hunger, global scale, biomass and CO2 indicating the initial prioritization opposing the terms after 2018 that include climate smart agriculture, perception, gender, tradeoff, study area, province, district and decision support system among others, conducting the orientation towards local adaptation of comprehensive policies and the "tradeoffs" introduction as a realistic way to sustainable pursue.

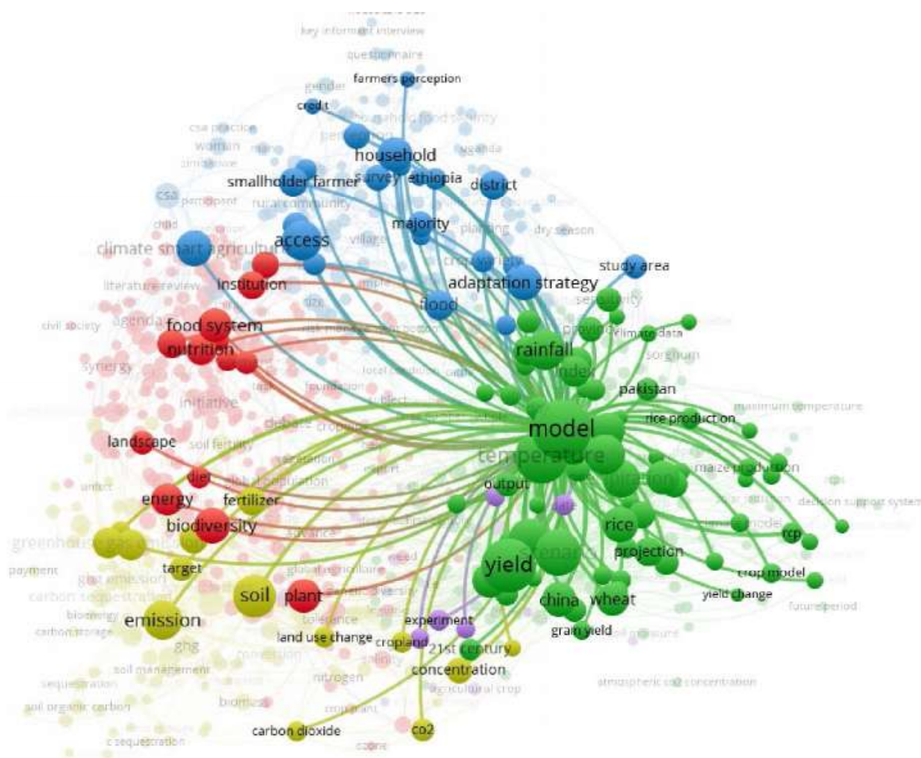

Figure 12. Word cluster map based on "climate change" AND "food security" AND "agriculture" SC interrogation – second cluster "model" relating to climate change and its relationships

Source: Processed by the authors in VOSviewer.

The second cluster resulted from the new database that is combining terms related to the climate change related objective of the interrogation, presents numerous links with all other clusters, having correspondence across multiple domains, targeting towards soil importance and the use of fertilizers, emissions and how that's impacting the food systems, the biodiversity and nutrition, through smallholder farmers and households that do represent an important stakeholder.

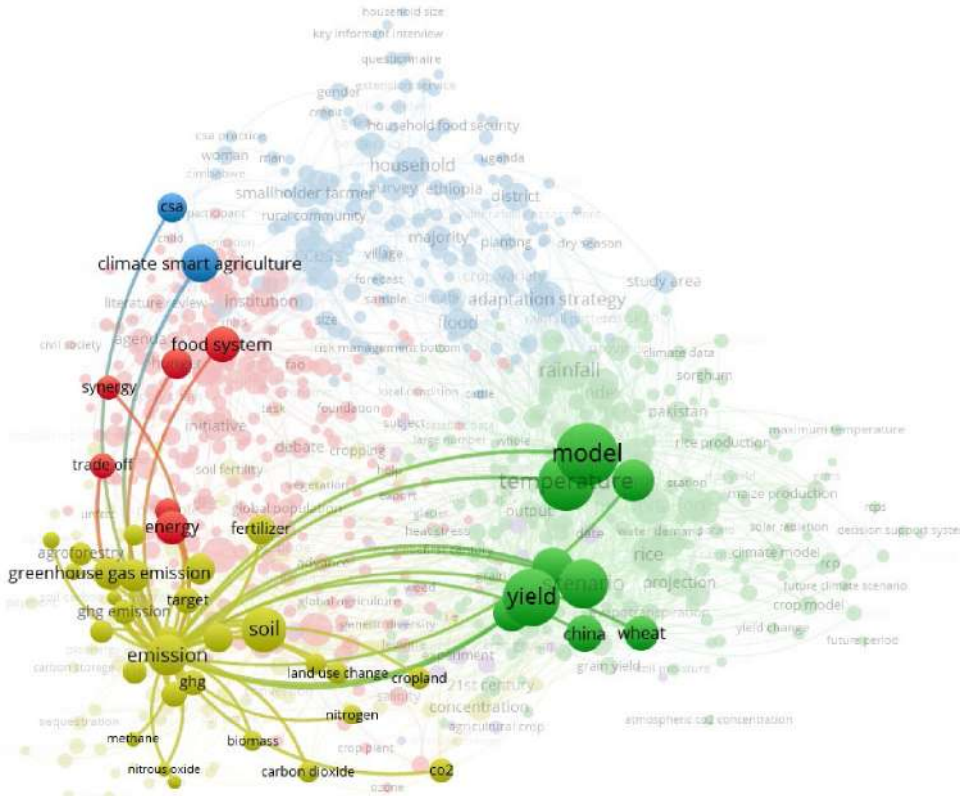

Figure 12. Word cluster map based on "climate change" AND "food security" AND "agriculture" SC interrogation – forth cluster "emission" relating to climate change and its relationships

Source: Processed by the authors in VOSviewer.

The yellow cluster presented above incorporates terms more relevant to the climate change cluster, also visible due to increased links to the green cluster. A climate-smart agriculture is indicated from the blue cluster as the focus towards eliminating everything that is harmful within the main word cluster. Another noticeable discussion from the links is that yield should not come with compromise.

Conclusion

Mobilizing social protection to increase resilience of livelihoods to successfully face direct and indirect impacts of climate change through activating an international standardized disaster risk management strategy to help developed and less developed countries to have a unison response when the challenges are global and micro-strategies can't resolve climatic disaster impacts on local or regional areas.

Building resilience of agricultural systems will help local communities, governments and international bodies to achieve a better effective and efficient resource management and eventually boost existing renewable sources by widening for example: fisheries management, implementing new agri-tech solutions such as vertical farms, urban farming, micro-green houses, and finally enhancing the diversity (resources diversification and variety changes in foods to improve consumer choice and reduce restrictions when necessary).

Investing in sustainable agricultural development (Research & Development) to find new ways and improve existing ones allowing smallholders (small farmers) to be an integral part of the national and regional plans.

Enabling adaptation through policies and institutions by establishing multi-layered links between farmers, producers, government and international organizations to reduce the negative impacts of climate changes and improving the state of food security for nations and countries.

Improving the market conditions will also contribute to food security stability from different perspectives – global trade and information systems that will be intensively used to outline the framework necessary to face climate unfavourability on a global scale, this also creates a strong regional and international cooperation framework for the security and safety of food networks, that starts from farmers and ends up at the consumers.

It is important to have an intersectoral and multidimensional approach in defining the monitoring indicators for the initial evaluation:

- the natural/geographical atmosphere in which the community lives, such as: climate and climate changes, relief, forests, pastures, mineral resources, rivers and lakes, land fertility, etc., availability and access to critical infrastructure and agri-food services (i.e., means of transport, agri-food markets, medical and educational centers, labor market, etc.);
- the socio-political and organizational context of the monitored region subject to evaluation;
- the different agricultural and non-agricultural activities carried out;
- the productive or non-productive assets owned by the natural persons in the area (types of agri-food products, crops, livestock, agricultural lands and their means of transport, etc.).

The warnings are addressed to beneficiaries in the (non) governmental surroundings or to the network liable to the chance of meals lack of confidence. It is essential to have all the necessary information before moving on to the actual strategic assessment and analysis stage, in order to effectively manage the food crisis. Therefore, for the preparation of a food security assessment it is important to follow a mission plan, which includes the vulnerable area under monitoring, a description of the target group affected by food insecurity factors.

The main limitations of the study are:

- Lack of accurate statistics that measures changes in food security in accordance with climate change.
- Inability to establish a quantitative model that explains the nature of the relation among food security, climate change and agriculture.

For future research the authors are evaluating statistical quantitative procedures to measure the interlinkage of these relevant topics and include other major topics in the mix.

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