Climate change and agriculture

Long-term changes in temperature and weather patterns are referred to as climate change which is a natural process happening over a long period of time. However, the rate at which the climate is changing over last few decades has become a major concern to human society.

Climate change has worsened the loss of land and freshwater resources, increased desertification, land degradation, and biodiversity loss, that exacerbate societal vulnerabilities, particularly in areas where natural resources are heavily reliant on the economy (FAO et al. 2018).

A huge proportion of world land area is used for agricultural purpose. Agricultural land accounted for around 4.8 billion hectares which makes 37 percent of total land area (FAO 2021).

The climate over land has been occurring at a quicker rate than the global average; For the period 2006–2015, the average temperature over land was 1.53°C higher than it was for the period 1850–1900, and 0.66°C greater than the global mean temperature rise (Arneth et al., 2019).

Because agricultural productivity is sensitive to changing climate conditions, climate change brings unprecedented challenges to agriculture system. Changes in climatic elements like temperature and precipitation, as well as the frequency and severity of extreme occurrences like droughts, floods, and windstorms, have a direct impact on agricultural and livestock production. Furthermore, increased concentrations of carbon dioxide have the potential to boost agroecosystem productivity. Nevertheless, increased temperatures combined with more unpredictable precipitation diminishes crop yield by significant value, outweighing the benefits of increased carbon dioxide (Walthall et al. 2012).

Soil and water are other key resources for agricultural production which are constantly interacting with the climatic elements. Healthy soils have an adequate level of nutrients to support healthy plants growth, moderately high levels of organic matter, a soil structure with good aggregation, optimum pH levels, and a healthy microbial community.

Climate change can affect the soils health both directly and directly (Bardgett et al. 2008; Karmakar et al. 2016).

The direct effects include temperature driven carbon loss through soil organic matter decomposition, change in soil microbial community composition, and carbon dioxide production (Bardgett et al. 2008). In addition, soil physicochemical properties such as soil structure, water retention, and nutrient availability also changes due to change in temperature and precipitation.

Indirectly, climate change affects soils through changes in plant productivity and vegetation structure. Increased CO2 concentration and temperature both enhance the plant growth, increases carbon input, thereby changing net carbon turnover (Van Veen et al., 1991; Allen et al. 1996).

References:

FAO, IFAD, UNICEF, WFP and WHO, 2018: The State of Food Security and Nutrition in the World 2018. Building climate resilience for food security and nutrition. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO. 2021. *Land use statistics and indicators statistics. Global, regional and country trends 1990– 2019*. FAOSTAT Analytical Brief Series No 28. Rome.

Walthall, C.L., J. Hatfield, P. Backlund, L. Lengnick, E. Marshall, M. Walsh, S. Adkins, M. Aillery, E.A. Ainsworth, C. Ammann, C.J. Anderson, I. Bartomeus, L.H. Baumgard, F. Booker, B. Bradley, D.M. Blumenthal, J. Bunce, K. Burkey, S.M. Dabney, J.A. Delgado, J. Dukes, A. Funk, K. Garrett, M. Glenn, D.A. Grantz, D. Goodrich, S. Hu, R.C. Izaurralde, R.A.C. Jones, S-H. Kim, A.D.B. Leaky, K. Lewers, T.L. Mader, A. McClung, J. Morgan, D.J. Muth, M. Nearing, D.M. Oosterhuis, D. Ort, C. Parmesan, W.T. Pettigrew, W. Polley, R. Rader, C. Rice, M. Rivington, E. Rosskopf, W.A. Salas, L.E. Sollenberger, R. Srygley, C. Stöckle, E.S. Takle, D. Timlin, J.W. White, R. Winfree, L. Wright-Morton, L.H. Ziska. 2012. Climate Change and Agriculture in the United States: Effects and Adaptation. USDA Technical Bulletin 1935. Washington, DC. 186 pages.

Arneth, A., F. Denton, F. Agus, A. Elbehri, K. Erb, B. Osman Elasha, M. Rahimi, M. Rounsevell, A. Spence, R. Valentini, 2019: Framing and Context. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems  
[P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D.C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)]. In press.

 Allen, Jr. L.H., J.T. Barker and K.J. Boote, 1996. The CO2 Fertilization Effect: Higher Carbohydrate Production and Retention as Biomass and Seed Yield. In: Global Climate Change and Agricultural Production. Direct and Indirect Effects of Changing Hydrological, Pedological and Plant Physiological Processes, Food and Agricultural Organization of the United Nations, Rome, Italy, ISBN-13: 9789251039878.

Karmakar R., Das I., Dutta D. and Rakshit A., 2016. Potential Effects of Climate Change on Soil Properties: A Review. *Science International, 4: 51-73.*

Bardgett, R., Freeman, C. & Ostle, N. 2008 . Microbial contributions to climate change through carbon cycle feedbacks. *ISME J* **2,** 805–814 . <https://doi.org/10.1038/ismej.2008.58>

Van Veen J A, Liljeroth E, Lekkerkerk L J A and van de Geijn S C 1991 Carbon fluxes in plant-soil systems at elevated atmospheric CO2 levels. Ecol. Applic. 1, 175–181.

Chapter 1

Introduction

In the terrestrial ecosystem, soil is the greatest carbon reservoir. Soil organic carbon (SOC) stores about 62 percent of terrestrial carbon and plays an important role in global carbon cycle and ecosystem functioning (Lal 2004). Soil organic matter (SOM) is a major source or soil carbon: SOM contains 58% organic carbon. SOM plays vital role in plant growth and food production. It promotes soil fertility, plant nutrition, and soil aggregate formation (Hoyle, 2013), improves water retention (Rawls et.al, 2003), and support soil biological activity (Benbi et al, 2018). Therefore, it is critical to explore potential influencing elements and determine the key driving forces that influence SOC, and CO2 exchange for agricultural sustainability and ecosystem balance.

SOC is very dynamic and exhibits a great variability across soil type, depth, land use, and climatic conditions. Important soil elements affecting SOC dynamics are soil aggregation and soil particle distribution. Organic carbon is usually protected within the well aggregated soil. By restricting air, water diffusion, and microbe accessibility, soil aggregates protect the SOC from microbial breakdown and mineralization (Razafimbelo et al., 2008; Wang et al 2019). Furthermore, the finer the aggregates, the better the protection of SOC, hence silt and clay particles hold the most organic carbon in the soil (Saha et al 2010). SOC content can also vary within a given soil; it is determined by the balance of net carbon input to the soil and net carbon losses from the soil. Land use is a key component that influences SOC input and release from the soil; forest and grassland typically have larger carbon inputs, whereas agriculture has the lowest. However, depending on the extent of soil manipulation and farming technique used, cultivation can have both positive and negative impacts on SOC storage and release (Godde et al., 2016). For instance, Luo et al. (2010) discovered that SOC at 10 cm and 30 cm below the surface in cultivated land, after 50 years of cultivation, was 51 percent lower and 0.9–73.4 percent lower than natural ecosystems, respectively. However, some other studies have reported increase in SOC in a cultivated soil over time by using conservation agriculture methods such as no tillage, irrigation, residue management, cover cropping, and crop rotation (Mandal et. al 2007; Page et al, 2020).

Temperature and precipitation are two major environmental factor that have a considerable impact on SOC. Zeng et al. (2021) revealed that mean annual precipitation (MAP) accounted for 81.8 percent and 13.8 percent of the variance in SOC chemical and physical fractionation, respectively, whereas mean annual temperature (MAT) contributed 1.5 percent and 34.7 percent, respectively. Climate change, particularly global warming, has been a major contributor to the acceleration of worldwide soil carbon losses. Soil respiration, plant growth, organic matter decomposition, and nutrient mineralization have all enhanced because of soil warming (Rustad et al, 2001). The effect of temperature on net primary production (NPP) and ecosystem respiration determines the net change in soil carbon in response to warming (Luo 2007). Plant and microbial biomass provide carbon to the soil, which is then released through microbial decomposition and soil respiration. Temperature increases both NPP and decomposition rate, but the net change determines whether C is stored or released from the soil (van Gestel et al., 2018).

Although several warming studies have revealed that as temperatures rise, the rate of SOC breakdown increases, resulting in more carbon being released from the soil as CO2 (Zhang et al., 2015; van Gestel et al., 2018), the temperature sensitivity of SOC decomposition is still a contentious issue (Knorr et al, 2005.; Davidson and Janssens, 2006). SOC is made up of two types of pools: labile (quickly decomposable) and recalcitrant (stable), each with a variable turnover time. Stable fractions are substantially more sensitive to temperature than labile fractions, according to studies (Jia et al, 2019, Lefevre et al. 2014; Zhou et al, 2018). Additionally, temperature is not the sole factor that influences decomposition rate; availability and accessibility of decomposers to the substrate, such as SOC, microbial abundance, precipitation, enzyme activity, soil properties, all play a crucial role. Decomposition rate increases with temperature if all other factors remain constant (Davidson and Janssens, 2006), but temperature is always interacting with several other variable in the soil and the decomposition rate is determined by the intricate interaction of all those variables (Jia et al, 2019). Soil water content, for example, is proportional to soil temperature. Warming can reduce soil water availability by increasing evapotranspiration and decreasing soil moisture (Lie et al, 2009), lowering the rate of SOC decomposition.

Soil microorganisms influences terrestrial carbon cycle either by driving decomposition of plant litter and soil organic matter or by contributing directly to the soil carbon pool (Bardgett et al. 2008). Warming alters soil temperature and moisture, as well as plant growth and biomass production, and root derived carbon via root exudates, thereby stimulating soil microbial growth and activity (Yin et al., 2013; Carlyle et al., 2011). Microbial biomass is highly correlated with plant-derived C via root exudation and decomposition (Eisenhauer et.al. 2017). Warming may increase ((Bell et al., 2010)), decrease (Mandal et al., 2007; Qi et al, 2016), or have no effects (Zhou et al., 2013) on soil microbial biomass. The response of soil microbial activity and biomass to warming is controlled by the precipitation regime, which may regulate soil moisture and substrate availability. Liu et al. (2016), after a four-year warming experiment, found that warming lowered MBC and microbial respiration when soil moisture was a limiting factor, but not under abundant moisture condition.

Soil respiration is another significant source of carbon loss in the soil. Nearly two-thirds of carbon loss in terrestrial ecosystems is due to soil respiration. Terrestrial ecosystems release carbon dioxide into the atmosphere through autotrophic (plant) and heterotrophic (microbe) respiration, with temperature having a significant impact on both (Luo and Zhou, 2006). Soil respiration increases when temperature rises, as does CO2 emission from the soil (Lefevre et al., 2014); nevertheless, soil respiration's temperature sensitivity tends to acclimate with time (Luo et al., 2001; Rustad et al., 2001). For instance, Melillo et al. (2002) observed that the annual CO2 flux from warmed plots at the Harvard Forest was 40 percent higher than control plots in the first year, but after a 6-year warming treatment, it steadily dropped to the level in control plots. Further, increases in respiration rates with soil temperature are limited until a temperature threshold of 25 °C is reached, after which they begin to decline as the temperature rises (Carey et al., 2016). Temperature sensitivity is also dependent on the covariation of other parameters that influence respiration, such as soil moisture and substrate availability (Davidson & Janseens, 2006). Wang et al (2014), in a meta-analysis, noticed that warming-induced soil moisture reductions, which were especially visible in dry areas, attenuated or even eliminated the stimulation of soil respiration by warming. Schindlbacher et al. (2012) observed similar results in a temperate forest warming and rainfall exclusion experiment. All of these findings support the theory that breakdown of SOC pools and soil respiration are sensitive to environmental fluctuations due to the substantial effects of temperature and moisture on microbial growth and activity.

We conducted a warming experiment from May to Oct in the Texas Tech research farm in Lubbock, Texas. In this study, we investigated the effects of warming and residue application on soil organic carbon pool, microbial biomass carbon, and soil respiration in irrigated and dryland agriculture. The warming was achieved by using open top chamber s(OTC). We hypothesized that (i) Soil warming enhances MBC and soil respiration while decreasing SOC content, (ii) Irrigation and residue improve soil moisture while lowering soil temperature, counteracting the warming impacts.

A meta-analysis of data collected at 17 sites from tundra, grassland, and forest shows that soil respiration under experimental warming increased at 11 sites, decreased at 1 site, and did not change at 5 sites ([Rustad et al. 2001](https://www.annualreviews.org/doi/full/10.1146/annurev.ecolsys.38.091206.095808)). It is commonly observed that the magnitude of response in soil respiration to warming decreases over time ([Rustad et al. 2001](https://www.annualreviews.org/doi/full/10.1146/annurev.ecolsys.38.091206.095808))

Many researches revealed that soil labile organic carbon pools were more ([Liski et al., 1999](https://www.sciencedirect.com/science/article/pii/S0929139316300385?casa_token=B1JkrjtYU10AAAAA:3IAMsj1ceapmppIpQbgNbFpCxdD8h1Y3jSQZLZR9KSocsXwOx_-9RJboaQNkWBa4M3gqcU9VrsU" \l "bib0135), [Thornley and Cannell, 2001](https://www.sciencedirect.com/science/article/pii/S0929139316300385?casa_token=B1JkrjtYU10AAAAA:3IAMsj1ceapmppIpQbgNbFpCxdD8h1Y3jSQZLZR9KSocsXwOx_-9RJboaQNkWBa4M3gqcU9VrsU" \l "bib0230)), less ([Knorr et al., 2005](https://www.sciencedirect.com/science/article/pii/S0929139316300385?casa_token=B1JkrjtYU10AAAAA:3IAMsj1ceapmppIpQbgNbFpCxdD8h1Y3jSQZLZR9KSocsXwOx_-9RJboaQNkWBa4M3gqcU9VrsU#bib0105)) sensitive to warming than resistant organic carbon pools, or they responded similarly to global warming ([Fang et al., 2005](https://www.sciencedirect.com/science/article/pii/S0929139316300385?casa_token=B1JkrjtYU10AAAAA:3IAMsj1ceapmppIpQbgNbFpCxdD8h1Y3jSQZLZR9KSocsXwOx_-9RJboaQNkWBa4M3gqcU9VrsU" \l "bib0070), [Leifeld and Fuhrer, 2005](https://www.sciencedirect.com/science/article/pii/S0929139316300385?casa_token=B1JkrjtYU10AAAAA:3IAMsj1ceapmppIpQbgNbFpCxdD8h1Y3jSQZLZR9KSocsXwOx_-9RJboaQNkWBa4M3gqcU9VrsU" \l "bib0120)).

All of these facts strengthen the idea that due to the strong effects of temperature on microbial decomposition of SOC pools, enzyme activities are sensitive to the changes in temperature.

The enhancement in soil MBC and MBN under increased precipitation could be due to higher aboveground plant productivity ([Niu et al., 2008](https://www.sciencedirect.com/science/article/pii/S0048969712015665?casa_token=hffDaVzi7kUAAAAA:RPCk9LfAfg8MEqh7kBUbLEeV-P_Aa1nWSDUP9JDQF6dRfFKYvEErVwxXoulupc-zKRpMYO_7EgU" \l "bb0095), [Yang et al., 2011](https://www.sciencedirect.com/science/article/pii/S0048969712015665?casa_token=hffDaVzi7kUAAAAA:RPCk9LfAfg8MEqh7kBUbLEeV-P_Aa1nWSDUP9JDQF6dRfFKYvEErVwxXoulupc-zKRpMYO_7EgU" \l "bb0140)), since microbial biomass was highly correlated with plant-derived C via root exudation and decomposition ([Ros et al., 2009](https://www.sciencedirect.com/science/article/pii/S0048969712015665?casa_token=hffDaVzi7kUAAAAA:RPCk9LfAfg8MEqh7kBUbLEeV-P_Aa1nWSDUP9JDQF6dRfFKYvEErVwxXoulupc-zKRpMYO_7EgU" \l "bb0100)).

Although we hypothesized that warming would decrease microbial biomass as it has in other studies ([16](https://acsess.onlinelibrary.wiley.com/doi/full/10.2136/sssaj2009.0036?casa_token=mP2xI34-_PEAAAAA%3AnVfNylkJctIieLXMrfKydvPIQAVQfeCWSMCSHrtK5R42SIarFTOqVSiN95oEGVmU6i0r6E9iwnG51p2D#bib16); [46](https://acsess.onlinelibrary.wiley.com/doi/full/10.2136/sssaj2009.0036?casa_token=mP2xI34-_PEAAAAA%3AnVfNylkJctIieLXMrfKydvPIQAVQfeCWSMCSHrtK5R42SIarFTOqVSiN95oEGVmU6i0r6E9iwnG51p2D#bib46)), microbial C instead increased with warming, despite minor decreases in soil moisture. Warming can increase root exudate production ([57](https://acsess.onlinelibrary.wiley.com/doi/full/10.2136/sssaj2009.0036?casa_token=mP2xI34-_PEAAAAA%3AnVfNylkJctIieLXMrfKydvPIQAVQfeCWSMCSHrtK5R42SIarFTOqVSiN95oEGVmU6i0r6E9iwnG51p2D#bib57)), and increased root exudation by Kentucky bluegrass, a dominant grass in our experimental plots, has increased microbial biomass in other systems ([27](https://acsess.onlinelibrary.wiley.com/doi/full/10.2136/sssaj2009.0036?casa_token=mP2xI34-_PEAAAAA%3AnVfNylkJctIieLXMrfKydvPIQAVQfeCWSMCSHrtK5R42SIarFTOqVSiN95oEGVmU6i0r6E9iwnG51p2D#bib27))

References:

Bardgett R.D., Freeman C., & Ostle N.J. (2008). Microbial contributions to climate change through carbon cycle feedbacks. ISME J 2:805–814

Ruimin Qi, Juan Li, Zhian Lin, Zhijie Li, Yanting Li, Xiangdong Yang, Jianjun Zhang, Bingqiang Zhao, 2016. Temperature effects on soil organic carbon, soil labile organic carbon fractions, and soil enzyme activities under long-term fertilization regimes. Applied Soil Ecology, Volume 102, 2016, Pages 36-45, ISSN 0929-1393.

Carlyle CN, Fraser LH, Turkington R (2011) Tracking soil temperature and moisture in a multi-factor climate experiment in temperate grassland: do climate manipulation methods produce their intended effects? Ecosystems 14:489–502

J.C. Carey, J. Tang, P.H. Templer, K.D. Kroeger, T.W. Crowther, A.J. Burton, J.S. Dukes, B. Emmett, S.D. Frey, M.A. Heskel, L. Jiang, M.B. Machmuller, J. Mohan, A. Marie, P.B. Reich, S. Reinsch, X. Wang, S.D. Allison, C. Bamminger, S. Bridgham, S.L. Collins, G. De Dato, W.C. Eddy, B.J. Enquist, M. Estiarte, J. Harte, A. Henderson, B.R. Johnson, K. Steenberg, Y. Luo, S. Marhan, J.M. Melillo, J. Peñuelas, L. Pfeifer-meister, C. Poll, E. Rastetter, A. Tietema **Temperature response of soil respiration largely unaltered with experimental warming** Proceedings of the National Academy of Sciences, 113 (2016), pp. 13797-13802,

Luo, Y., Wan, S., Hui, D. & Wallace, L.L*.* (2001). Acclimatization of soil respiration to warming in a tall grass prairie. *Nature,* *413*, 622–625.

Yin H, Li Y, Xiao J, Xu Z, Cheng X, Liu Q (2013) Enhanced root exudation stimulates soil nitrogen transformations in a subalpine coniferous forest under experimental warming. Glob Change Biol 19:2158–2167

Xiaoqi Zhou, Chengrong Chen, Yanfen Wang, Zhihong Xu, Hongyan Han, Linghao Li, Shiqiang Wan, (2013) Warming and increased precipitation have differential effects on soil extracellular enzyme activities in a temperate grassland, Science of The Total Environment, Volume 444, 2013, Pages 552-558, ISSN 0048-9697,

Lal R. Soil carbon sequestration impacts on global climate change and food security. Science. 2004;304(5677):1623–7.

T.M. Razafimbelo, A. Albrecht, R. Oliver, T. Chevallier, L. Chapuis-Lardy, C. Feller

**Aggregate associated-C and physical protection in a tropical clayey soil under Malagasy conventional and no-tillage systems**

Soil Research, 98 (2) (2008), pp. 140-149,

van Gestel, N., Shi, Z., van Groenigen, K. *et al.* Predicting soil carbon loss with warming. *Nature* **554,** E4–E5 (2018). <https://doi.org/10.1038/nature25745>

*Zhou, X. H.*, *Xu, X.*, *Zhou, G. Y.*, & *Luo, Y. Q.* (*2018*). *Temperature sensitivity of soil organic carbon decomposition increased with mean carbon residence time: Field incubation and data assimilation*. *Global Change Biology*, *24*, *810*–*822*.

A. Mandal, A.K. Patra, D. Singh, A. Swarup, R.E. Masto

**Effect of long-term application of manure and fertilizer on biological and biochemical activities in soil during crop development stages**

Bioresource Technology, 98 (2007), pp. 3585-3592

X. Wang, Y. Li, X. Gong, Y. Niu, Y. Chen, X. Shi, W. Li

**Storage, pattern and driving factors of soil organic carbon in an ecologically fragile zone of northern China**

Geoderma, 343 (2019), pp. 155-165,

S.K. Saha, Ramachandran, P.K. Nair, V.D. Nair, B. Mohan Kumar

**Carbon storage in relation to soil size-fractions under tropical tree-based land-use systems**

Plant and Soil, 328 (1–2) (2010), pp. 433-446,

Davidson, E. A. & Janssens, I. A. Temperature sensitivity of soil carbon decomposition and feedbacks to climate change. *Nature* **440**, 165–173 (2006).

Rubing Zeng, Yujie Wei, Jianjia Huang, Xin Chen, Chongfa Cai,

Soil organic carbon stock and fractional distribution across central-south China,

International Soil and Water Conservation Research,

Volume 9, Issue 4,

2021,

Pages 620-630,

ISSN 2095-6339,

Eisenhauer, N., Lanoue, A., Strecker, T. *et al.* Root biomass and exudates link plant diversity with soil bacterial and fungal biomass. *Sci Rep* **7,** 44641 (2017). https://doi.org/10.1038/srep44641

R. Lefevre, P. Barre, F.E. Moyano, B.T. Christensen, G. Bardoux, T. Eglin, C. Girardin, S. Houot, T. Kätterer, F. Oort, C. Chenu

**Higher temperature sensitivity for stable than for labile soil organic carbon–evidence from incubations of long-term bare fallow soils**

Global Change Biology., 20 (2014), pp. 633-640

*Rustad, L.E.*, *Campbell, J.L.*, *Marion, G.M.*, *Norby, R.J.*, *Mitchell, M.J.*, *Hartley, A.E.*, *Cornelissen, J.H.C.*, and *Gurevitch, J.* *A meta-analysis of the response of soil respiration, net nitrogen mineralization, and aboveground plant growth to experimental ecosystem warming*. *Oecologia* *2001* *126* *543*–*562*

*Bell, T. H.*, *Klironomos, J. N.*, & *Henry, H. A. L.* (*2010*). *Seasonal responses of extracellular enzyme activity and microbial biomass to warming and nitrogen addition*. *Soil Science Society of America Journal*, *74*(*3*), *820*–*828*.

Hoyle, F. (2013). *Managing Soil Organic Matter: A Practical Guide.* Kingston, ACT: Central Queensland Soil Health.

W.J. Rawls, Y.A. Pachepsky, J.C. Ritchie, T.M. Sobecki, H. Bloodworth,

Effect of soil organic carbon on soil water retention, Geoderma,

Volume 116, Issues 1–2, 2003, Pages 61-76, ISSN 0016-7061,

Benbi, D.K., Sharma, S., Toor, A.S. Brar, K., Sodhi, G.P.S. Grag A.K. (2018) Differences in soil organic carbon pools and biological activity between organic and conventionally managed rice-wheat fields. *Organic Agriculture.* **8,** 1–14 (2018). <https://doi.org/10.1007/s13165-016-0168-0>

Godde CM, Thorburn PJ, Biggs JS and Meier EA (2016) Understanding the Impacts of Soil, Climate, and Farming Practices on Soil Organic Carbon Sequestration: A Simulation Study in Australia. *Frontier in Plant Science.* 7:661. doi: 10.3389/fpls.2016.00661

Zhongkui Luo, Enli Wang, Osbert Jianxin Sun, Soil carbon change and its responses to agricultural practices in Australian agro-ecosystems: A review and synthesis, Geoderma, Volume 155, Issues 3–4,

2010, Pages 211-223, ISSN 0016-7061,

Luo, Z., Wang, E., Sun, O. J., Smith, C. J., and Probert, M. E. (2011). Modeling long-term soil carbon dynamics and sequestration potential in semi-arid agro-ecosystems. *Agric. For. Meteorol.* 151, 1529–1544. doi: 10.1016/j.agrformet.2011.06.011

Page KL, Dang YP and Dalal RC (2020) The Ability of Conservation Agriculture to Conserve Soil Organic Carbon and the Subsequent Impact on Soil Physical, Chemical, and Biological Properties and Yield. *Front. Sustain. Food Syst.* 4:31. doi: 10.3389/fsufs.2020.00031

K. Zhang, H. Dang, Q. Zhang, X. Cheng

**Soil carbon dynamics following land-use change varied with temperature and precipitation gradients: evidence from stable isotopes**

Glob. Chang. Biol., 21 (7) (2015), pp. 2762-2772

Chapter 2

Warming effects on plant growth, biomass yield of cotton.

Introduction

Climate has an impact on crop productivity; temperature and precipitation, in particular, are crucial for completing the crop cycle. In recent years, climate change, particularly warming, has significantly altered the crop cycle and production. The quality and quantity of crops grown have been severely impacted by changes in global temperature and precipitation patterns (Rosenzweig et al, 2014). According (Lobell & Field, 2007) temperature and precipitation alone contribute for 30% or more of the fluctuation in worldwide average yields for the world's most extensively produced crops. As a result, it is critical to investigate climate change mitigation techniques and crop adaptation in order to maintain agricultural sustainability in the face of changing climate.

Crop yields can be affected both positively and negatively as a result of global warming (Ostberg et al., 2018). On the one hand, it shortens the growing season, creates heat stress, which enhance evapotranspiration and moisture stress, and hence reduces overall crop yield (Zhao et al. 2017; Lobell et al. 2013). Warming, on the other hand, is projected to increase CO2 levels in the atmosphere, which will help crop growth and yield by enhancing water use efficiency and photosynthesis, especially in C3 plants (Hatfield & Dold, 2019). However, several soil and environmental variables such as precipitation, plant nutrients availability, and soil moisture content, limit crop growth and yield interactions with increased CO2 (Kimbell, 2010). As a result, CO2 fertilization does not always compensate for increased water demand or the shortening of already short growing seasons for most annual crops (Ostberg et al., 2018). Moreover, different geographical regions may have different sensitivity to climate change. Ramankutty et al., 2002 demonstrated that the regions that are already on the edge of temperature or precipitation limit for cultivation are most vulnerable to changes in climate. Their climate sensitivity analysis indicated that in the US, the Great Plains region is the most susceptible to changes in precipitation, while the northwestern and north-central states are the most sensitive to changes in temperature.

Cotton production in the United States is centered in the Great Plains. The Great Plains region produces about 30 to 35 percent of the cotton crop in the United States and 5 to 8% of the world's cotton yield (USDA-NASS, 2020). However, new statistics reveal that cotton production in the Texas high plain is declining – upland cotton production in Texas declined by 8% in 2019 compared to 2018. (USDA-NASS, 2020). wet and mild weather during planting season in may, as well as hot and dry conditions during the critical growth phase in august, are major contributing factors, according to the (PCG, 2020). Another key barrier for long term-cotton cultivation in Texas' high plains is moisture stress. Irrigation is used to irrigate about 60% of the agricultural land in this region (Brett, 2013). Groundwater withdrawn from the Ogalala aquifer, the world's largest aquifer, is the main supply of irrigation water. However, the Ogalala's water level has been dropping in recent years. Because of the region's semi-arid environment, poor ground water recharge rate, and little rainfall, only about 10-20% of the land that is currently irrigated can be sustainably irrigated (Brett, 2013). Therefore, regenerative dryland farming can be only viable strategy for ensuring the long-term viability of cotton production in the high plains.

Cotton physiology – role of temperature and moisture

Literatures showing Warming impact on cotton production – moisture & temperature interaction to determine yield

Aim & objectives -- hypothesis

Kimball BA *(2010) Lessons from FACE: CO2 Effects and Interactions with Water, Nitrogen, and Temperature. The Handbook of Climate Change and Agroecosystems, eds Hillel D, Rosenzweig C (Imperial College Press, Singapore), pp 87–107.*

David B Lobell and Christopher B Field 2007 Environ. Res. Lett. **2** 014002

Rosenzweig, C., Elliott, J., Deryng, D., Ruane, A. C., Müller, C., Arneth, A., Boote, K. J., Folberth, C., Glotter, M., Khabarov, N., Neumann, K., Piontek, F., Pugh, T. A. M., Schmid, E., Stehfest, E., Yang, H., and Jones, J. W.: Assessing agricultural risks of climate change in the 21st century in a global gridded crop model intercomparison, P. Natl. Acad. Sci. USA, 111, 3268–3273,

Ramankutty, N., Foley, J. A., Norman, J., and McSweeney, K.: The global distribution of cultivable lands: current patterns and sensitivity to possible climate change, Global Ecol. Biogeogr., 11, 377–392, <https://doi.org/10.1046/j.1466-822x.2002.00294.x>, 2002

Lobell, D. B. et al. The critical role of extreme heat for maize production in  
the United States. Nat. Clim. Change 3, 497–501 (2013).  
Zhao, C. et al. Temperature increase reduces global yields of major crops in  
four independent estimates. Proc. Natl Acad. Sci. USA 114, 9326–9331 (2017).

Hatfield JL and Dold C (2019) Water-Use Efficiency: Advances and Challenges in a Changing Climate. *Front. Plant Sci.* 10:103. doi: 10.3389/fpls.2019.00103

USDA\_NASS, 2020 Annual cotton review, USDA NASS monthly crop production report.

PCG 2020, Cotton news, plain cotton growers

Walton Brett, 2013. Texas High Plains Prepare for Agriculture without irrigation. Water news