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Near-term Problems in Meeting World Food Demands at Regional Levels: A Special Issue Overview

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CORE IDEAS

- Food insecurity must be addressed
- Agronomic production systems must suit local conditions
- Near-term challenges need to be addressed to maintain productivity

Abstract

Growing food, feed, and fiber in a manner sustainable for future generations is the starting point for improved food security. As the world population continues to grow, it is imperative to improve many aspects of agronomic production systems to better suit local conditions. This special issue of Agronomy Journal examines what agronomists see as today's or near future problems that are currently looming for different regions of the world. Authors from Africa, Asia, and South and North America were invited to write forum papers for this special issue. Some of the current agronomic practices and policies are unsustainable for diverse reasons. Workforce development, climate challenges, soil degradation, water limitations, and pest problems are discussed. Suggested solutions to these problems include

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integrated techniques, which need to be implemented in knowledgeable systems approaches, to sustain the environment and improve food security. It is hoped that this special issue serves as an outreach platform to the global community to improve communication and spark new collaborations.

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Introduction

The world population continues to grow. It currently stands at 7.8 billion and is projected to increase to 9.8 billion people by 2050 and 11.2 billion by 2100 (United Nations Department of Economic and Social Affairs; https://www.un.org/development/desa/en/news/population/world-population-prospects-2017.html). Most of the population growth is expected to be concentrated in the least-developed, resource-poor countries of Asia and Africa. Although the Global Food Security Index reported continuous food security improvements between 2012 to 2018, a deterioration of the index for both 2019 and 2020 has been noted (GFSI, 2020). The reasons for the decline are multifold but the COVID-19 pandemic likely made the already fragile global food security landscape worse in 2020. The situation is likely to get more severe in the future as climate change is predicted to negatively impact crop productivity.

So how do we, as agronomists, aid in alleviating hunger and food insecurity? Evidence suggests that economic growth does not automatically ensure success in reducing food insecurity (FAO, 2009) but that the source of growth is important too. For example, FAO (2009) reports that growth originating from agricultural activities benefits the poorest at least twice as much as growth from non-agricultural sectors. This is directly linked to the fact that agriculture is the backbone of the economies in the least-developed countries, since approximately 75% of the population live in rural areas with their income directly linked to agriculture. Even with so many interconnected to agriculture, in 2019 nearly one in ten people were affected by severe food insecurity and about 2 billion people (25% of today's world population) did not have access to nutritious and sufficient food supply (GFSI, 2020).

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There are many reasons for food insecurity, with cropping system agriculture just one link in the labyrinth of the food chain. Nevertheless, growing food, feed, and fiber in a manner sustainable for future generations is the starting point for improved food security. Worldwide problems needing attention to continuously feed an expanding population are numerous. A short list of looming problems include extreme climate events, which result in near-term problems such as crop failure and long-term problems such as loss of fertile soil due to erosion or saltwater intrusion; local and national responses to COVID-19 disrupting labor, distribution, and supply chains; and increasing temperatures and atmospheric greenhouse gas concentrations, as well as depletion of fresh water supplies, which all impact crop growth and pest pressure. Understanding the diversity and extent of these problems and development of potential solutions are needed to target research efforts, so that effective solutions can be implemented using scale-independent methods. In addition, solutions must be extended to end-users and be affordable. Implementation of new technologies or policy changes to help adoption [either with carrot (rewards) and/or stick (punitive measures) approaches] may be needed.

Often, the 2050 timeframe has been used to express the long-term implications of what needs to occur. However, there are emerging problems that need to be addressed now, or in the near future, to maintain healthy agroecosystems and food supplies. This special issue of Agronomy Journal examines what agronomists see as today's or near future problems that are currently looming for different regions of the world. Authors from Africa, Asia, and South and North America were invited to write forum papers for this special issue of the Agronomy Journal. We believe this is important considering that often Agronomy Journal articles focus on research conducted to address agronomic issues in North America, while different types of problems may need attention in other countries. It is hoped that this special issue serves as an

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outreach platform to the global community to improve communication and spark new collaborations among agricultural researchers, as, in some cases, similar problems and solutions have been highlighted in several of the papers from countries in different continents.

Paper contributions have been grouped into five categories focusing on (i) critical issues facing food production and workforce needs (ii) conservation/sustainable agriculture strategies to achieve food security (iii) soil health management considerations and impact on food production, (iv) climate change and impacts on food security, and (v) pest management challenges. This introduction gives a short overview on the main points discussed in each category.

Critical issues facing food production and the Ag workforce

Lamm et al. (2021) collected data from academic faculty and industry representatives to examine issues facing food production in the near future using the Delphi process to come to consensus. While the sample size was limited (single land grant university in the Southern U.S. used for academic faculty), the eight main categories highlighted in the Lamm et al. (2021) paper are themes explored in many of this issue's forum papers and provides a framework that outlines pressing issues and knowledge gaps for the agriculture and agronomy industries. Experts on the panel were in 90 to 100% consensus on three hot topic issues: soil health and water usage; climate and environmental factors; and research and collaboration (more data on the topics, interdisciplinary collaboration, and sharing of information within research groups as well as with farmers). In addition, workforce training (see Erickson et al. 2021), accessibility of germplasm (see Smith et al. 2021) , chemical

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usage, (including weed resistance (see Clay, 2021 and disease problems discussed in Byamukama et al. 2021) and economic stability and governmental policy focused on the agricultural sector (discussed in Joshi et al. 2021, and Barrera et al. 2021) were recognized as urgent topics that must be addressed to continue to have sustainable production agriculture in the future.

As technology becomes more common place in crop production, a well-trained workforce is imperative to empower the best use of the technology (Erickson et al. 2021). This means that users will need training in crop production best management practices, as well as when, where and what technology is appropriate to be deployed in specific circumstances. Precision agriculture (PA) applications are still expanding, but the approaches used are multifold, and dependent on the farm characteristics. PA can improve production efficiency and stability by matching inputs to crop needs based on weather, soil, and use of algorithms that are developed based on past data. But the high cost of many technologies and the technological literacy and skills needed for many of the applications requires a well-trained (and well-paid) workforce to help farmers navigate the (often many layered) systems and aid in the implementation of best practices. This often limits accessibility to large farms only, leaving smaller producers without the benefits. Scale neutral practices for PA and digital agricultural applications would provide greater access to all agriculture producers, which should help in sustainability and production increases needed to feed an expanding population**.**

Global food security depends on germplasm exchange and continual improvement of most food crops (Smith et al. 2021). It is essential to continue and maintain widespread germplasm exchange for crops so that plant breeders and other scientists can work collaboratively around the world to achieve greater gains in crop yields through improved

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tolerance or resistance to pest pressure or incorporating genes that may have been lost during earlier selection (e.g., bottleneck). Smith et al.(2021) argue against any new policies that would restrict germplasm access, as this could negatively impact future world crop production and food security.

Conservation agriculture and food security

The current conventional cropping systems as large-scale monoculture, though highly productive to feed the growing world population, often have adverse impacts on the environment causing major challenges to the sustainability of today's typical cropping system. As shown by Joshi et al. (2021), Barrera et al. (2021) and Wortmann et al. (2021) the situation is more severe in the rural regions of the underdeveloped countries due to limited resources available to the farming communities.

There is an urgent need to modify food systems at local and regional levels that include an overwhelming majority of small scale (i.e., <10 ha) farmers, not only to increase food production but also to make the systems more efficient and sustainable. Nepal (Joshi et al., 2021) and the Andean region of South America (Barrera et al., 2021) have differences in climate but similarities in landscapes (steep sloping mountainous landscapes with thin depths of topsoil). As outlined by the two papers, there are similar challenges to small scale farming and conservation agriculture (CA) practice adoption. A majority of farmers in both regions lack financial capital and continue to utilize traditional subsistence farming practices (e.g., high use of tillage, traditional seeding rates with old-type varieties). These regions also lack government policies to help in extension efforts needed to demonstrate the advantages of CA practices and provide economic incentives (e.g., crop insurance or input subsidies) to increase adoption of CA practices. Although CA practices, such as reducing tillage, conserving crop residue as a soil cover, and installing diversion ditches to regulate water flow, have been

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shown to improve soil health and crop yield, reduce soil erosion, and increase profitability (Barrera et al., 2021) adoption is low. In the Mid Hill farming region of Nepal, no-till alone could sequester 140 kg soil organic carbon (SOC) ha^{-1} yr^{-1} and no-till with residue addition increasing the SOC by up to 480 kg ha^{-1} yr^{-1}) in the Terai rice-wheat systems (Ghimire et al., 2012). In the mountains and hills of Nepal, adoption of conservation buffer systems reduces soil erosion and improves overall farming system performance (Schwab et al., 2015). In the Andes, erosion rates exceed the average soil formation rate by 9 to 286 times (Barrera et al., 2021) making the current agricultural practices unsustainable and threatening the livelihood of farmers and food security. In addition, the silt deposition in streams and reservoirs reduces water storage capacity and results in poor water quality for downstream users.

The rotation of perennial grass or grass-legume mixtures with annual crops (i.e., ley rotation) is practiced by farmers all over the world as a means to improve soil and farming system productivity, profitability and sustainability. Wortmann et al. (2021) reviews research results of ley versus fallow rotations with annual crops in research conducted within 15^o latitude of the equator in tropical Africa. They conclude that opportunities for perennial grass ley rotated with annual crops are abundant in tropical Africa. While they underscore that land for annual crop production for subsistence farmers is very scarce, they believe ley rotations have a place in the farming systems. Perennial grasses in ley rotations can be used to reverse the often too common problem of soil degradation through increased soil organic matter, carbon sequestration, and overall improvement soil physical properties. In addition, most farmers in rural areas own livestock and ley rotations offer opportunities to provide much needed fodder for livestock, therefore enhancing economic growth. However, the authors realize that there still challenges, both political and social, to adoption of ley rotations. For example, overgrazing of arable lands during the dry season can be damaging to the ley and reverse the

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beneficial attributes of the systems. Since most of the land in rural areas is communally owned, this overgrazing can be managed by strong local government policies.

Haarhoff and Swanepoel (2021) review current status of rainfed soybean production in South Africa. They note that despite recent genetic advancements and the introduction of novel weed management strategies, soybean yield over the past years has remained static in South Africa. This is likely because inconsistent rainfall, high temperatures and soil compaction limit soybean productivity in many regions in South Africa. They suggest adoption of no-till production practices as a way to mitigate the impacts of drought and high temperature. However, they emphasize that local soybean growers are very concerned with yield penalties under less soil-disturbance practices and that there is need to conduct long-term research to understand the interaction of these practices on yield.

McLennon et al. (2021) examine alternatives to the current conventional production systems focusing on systems that involve sustainable use of natural resources without adversely impacting the environment. While at this time the concepts are mainly theoretical, they examine how regenerative agriculture, permaculture and smart technology (precision and digital agriculture) can evolve in the future to support global sustainable agriculture and food security. Regenerative agriculture is a set of holistic approaches that emphasize and make the most of naturally occurring beneficial soil-plant interactions while relying less on external inputs and mimicking ecological principles (Perry, 1995). In fact, the literal meaning of the word “regeneration” is implied since regenerative agriculture seeks to recondition agricultural land to a higher state after it has been utilized using practices that degrade the soil. Regenerative agriculture is soil-centric, it seeks to make the soil more resilient. McLennon et al. (2021) argue that regenerative agriculture would be more beneficial to smallholder subsistence farmers that lack financial resources for more intensive productions systems.

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They see regenerative agriculture as a better fit to alleviate problems in food supplies in such scenarios because the concept emphasizes practices that are location specific and therefore would prescribe agricultural cropping systems based on local needs and niches rather umbrella initiatives prescribed at regional or country levels. Permaculture is a broad term that describes a wide range of farming practices and systems that optimize the interactions between the soil-plant systems. This concept views many of the farming practices as interrelated and utilizes ecological functionalities to maximize ecosystem health while providing ecosystem services (Zahra & Gambiza, 2019). In addition, precision agricultural techniques would be used to implement best management practices at the local level. They argue that more robust research in integrated permaculture techniques is needed to meld regenerative agriculture, precision agriculture, and digital agriculture into seamless practices aiming to improve sustainable cropping systems and improve global food security.

Water management is key component of sustainable intensification of cranberry production in Massachusetts (Jeranyama and Kennedy, 2021). Specifically, cranberry growers have traditionally used overhead sprinkler irrigation, running irrigation pumps continuously during cold weather in spring, to protect susceptible buds from frost damage. This method uses a lot of water, resulting in nutrient leaching, high energy and labor costs. Jeranyama and Kennedy (2021) evaluated three thermal time models as decision tools for initiating spring frost protection and two methods for applying irrigation for frost protection. One of the models, WI(30-5) provided the most accurate estimates for the phenology of buds. Cycling irrigation (turning pumps on and off during the cold-snaps rather than continuous operation) reduced water use from 30 to 80%. Although cycling irrigation caused slightly greater bud damage compared to conventional irrigation, it did not reduce yield. They suggest irrigation cycling

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as a viable method of protecting cranberry buds from frost damage while also providing other environmental benefits.

Yuan et al. (2021) used a novel system of rice and crayfish in waterlogged areas near the Han and Yangtze Rivers in China to examine if this system enables growers to better use resources compared with a rice-wheat rotation and a crayfish monoculture. Using rice + crayfish reduced fertilizer and pesticide input in the rice, and fishery drugs in crayfish production portion of the cycle. In addition, farmers income increased by 9 to 48%. These types of unique rotations may be more environmentally friendly and efficient than traditional cropping systems and highlight the need to examine new systems that better serve both consumers and producers.

Soil health management considerations and impacts of food security

What is the relationship between soil health and global food security? Bagnall et al. (2021) explore this relationship and offer a comprehensive strategy to achieve adoption of soil health systems at scale. The U.S. plays a significant role in global food production because of its soil resources, conducive climate for many different crops, advances in research, innovations that farmers can readily adopt, and extension networks that demonstrate and showcase new concepts. In fact, the U.S. is one of the world's largest exporters of grain and oilseed crops. This means that interruption to U.S. crop production can have substantial impacts on international grain markets and hence food security. However, the need to address the challenges to food security (i.e., intensifying crop production systems) often leads to agricultural practices that degrade soils, reduce ecosystem services, and eventually, crop

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failures (Bagnall et al., 2021). They suggest the solution will be recognizing the connections between soil health and food security and that both be addressed simultaneously.

Obour et al. (2021) examine the role cover crops can play to improve soil health in the dryland region of the US Great Plains. The Great Plains is a major grain-producing region accounting for most of the wheat (62%) and sorghum (96%) produced in the U.S. (USDA-NASS, 2019). The cropping systems in the region utilize a fallow phase as a risk -avoidance strategy where water stored during the fallow phase limits future crop failure and stabilizes yield. The length of the fallow period ranges from 10 to 21 months depending on location and cropping system (Carr et al., 2021). While the adoption of no-till practices has had a positive impact on soil and water conservation practices, the challenges relating to controlling herbicide resistant weeds, and soil compaction poses a threat to the long-term sustainability of the no-till practices in the region. Obour et al. (2021) discuss the potential of integrating cover crops to replace fallow as a solution to the above problems while also increasing soil organic matter, improving soil fertility by scavenging nutrients, and providing livestock fodder.

In Sub-Saharan Africa, food production increases have not met the regional demand and this has led to significant food insecurity (Wortmann & Stewart, 2021). In response to persistent food insecurity in the region, there are calls for sustainable intensification (SI) of food production. Sustainable intensification is an approach that uses innovations to increase productivity on existing agricultural land while maintaining positive environmental and social impacts (Stewart et al., 2018) . Most of food production in Sub-Saharan Africa comes from the tropical savanna but the gap between actual and potential yield remains very wide. Wortmann & Stewart (2021) examine soil fertility management, a component of SI, as a way to increase yield and profit potential for farmers. They utilize data collected in the upper and

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lower elevation savannas since 1985 to determine crop N, P and K response functions for six major crops in each savanna region. These yield response functions were then used for profitability analyses. They conclude that while crop production increased with increasing fertilizer use, this was still not enough to meet the growing food demand in Sub-Saharan Africa. They suggest adoption of other mitigation strategies including regenerative soil fertility enhancing practices.

Climate change and impacts on food security

There is growing evidence that globally, climate is changing. This change is characterized by increasing average surface temperatures and increasing intensity and frequency of extreme events (IPCC, 2013). For example, mean precipitation across many mid-latitudes and subtropical dry regions will likely decrease while in mid-latitude set regions precipitation will likely increase. IPCC (2013) also predict that precipitation events over large land masses in the mid-latitude and the wet tropical regions will be more intense and frequent by 2100. These projections in climate change have serious implications for crop production across all regions of the world. O’Brien, et al. (2021) examine how technological advances, as well as improved genetic resources, in the past have resulted in increases in yield potential and actual yield, thus narrowing the yield gap, but warn that climate change along with land degradation due to management practices such as tillage, crop expansion and monocropping, threatens these advances. They suggest management strategies that utilize novel technologies such as artificial intelligence, machine learning and digital agriculture to help understand the interactions among different components of agricultural systems, much like those proposed by McLennon et al. (2021). O’Brien et al. (2021) introduce a genotype x environment x management framework that is based on advanced understanding of genetic by environment interactions and new technologies in agronomic management to form the basis for strategies

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in crop production of the future. Climate change has even more severe implications for smallholder farming communities since they primarily depend on rainfed agriculture and forest resources for their livelihood (see Joshi et al. and Barrera et al. in this series).

Sedebo et al., (2021) examined the impact of smallholder farmers' climate-smart adaptation practices on crop production efficiency in in one district in Southern Ethiopia. They surveyed 600 smallholder crop producers in six rural regions and estimated the technical efficiency (TE) using Stochastic Frontier Analysis. They report that 73% of farmers in the district adopted at least one adaptation practice to combat climate change. Practices included terracing, crop diversification, adding soil amendments, and/or varying planting and harvesting schedules. In addition to climate-smart practices, farming experience, education level, access to extension services, ownership of livestock influenced which practice(s) were adopted. Sedebo et al. (2021) recommended that policy makers incorporate smallholder farmers' climate-smart practices into national programs to improve effective responses to climate change.

Kwon et al., (2021) focus their attention to agriculture's impact on sustainability. They acknowledge that the agriculture sector is a major contributor to global warming through greenhouse gas (GHG) emissions and discuss key agricultural practices that contribute to GHG emission. Currently life-cycle analysis (LCA) is the method used to assess for environmental sustainability of a farming system. Typical LCA includes cradle to farm-gate where activities related to production of farm inputs and crops are evaluated in terms of energy consumption, GHG emissions and other environmental attributes. They identify a wide range of mitigation strategies including manufacturing fertilizer and chemicals that require less fossil fuel inputs, reducing on-farm energy consumption, optimizing farm fertilizer placement by using precision agriculture and increasing soil carbon stocks.

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However, for these strategies to succeed, and for them to be adopted at different scales of farming, new policies and incentives are needed.

Pest management challenges

Prior to the 1950s weeds, in the US and much of the world, were mostly controlled with a wide range of mechanical and cultural methods. However, the advent of highly efficacious, selective, and relatively inexpensive herbicides in the 1950s changed traditional weed management methods to herbicidal weed control in only a few years. Clay (2021) discusses the benefits this technology. However, the repeated applications of the same herbicides over long periods of time have selected for resistant weed biotypes so that farmers are facing a major challenge about the use and reliability of the herbicide paradigm. Clay (2021) encourages researchers to explore alternative strategies that include more integrated approaches to crop management, mechanical techniques, and as well as new innovations such as drones, artificial intelligence, and robotics.

Plant disease epidemics have been devastating worldwide, causing severe crop yield losses. The Northern Great Plains (NPG) of the U.S. is a major crop producing region accounting for 25% of total cropland in the country (USDA, 2021). Outbreaks of plant diseases are of great concern to food security as the region plays a significant role in food and feed production for the nation and worldwide. Byamukama et al. (2021) examine risk factors that increase chances of crop disease epidemics. The changing global climate, increases in seed trade, and movement of agricultural produce and people around the world all contribute to the chances for introducing new pathogens to new environments resulting in new diseases and new epidemics. They also discuss how indiscriminate use of fungicides over a long period of time has resulted in development of fungicide resistance in a number of fungal pathogens. They suggest a number of strategies to mitigate disease epidemic threats to crop production

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including utilizing advances in computing such as artificial intelligence and machine learning to understand a pathogen’s biology and response to weather, and plant risk factors to better predict and mitigate disease outbreaks.

When reading through this overview, the reader can see that there are many patterns and similarities in what agronomists see as near-term problems and solutions. A common thread is that we need to be mindful of how agricultural practices are influencing nature and how nature is influencing agricultural practices. What is clear is that some of the practices used today are unsustainable due to soil degradation, resistance, or water resource depletion. New techniques, whether it be new varieties, precision agriculture, conservation agriculture, integrated permaculture, or others will not help with food security unless they are implemented in a knowledgeable systems approach. It is hoped that this issue will provide insight into what is seen as the problems and provides sparks of interest to tackle these issues with the goal to make sure everyone is eating nutritious healthy foods in 2050 and beyond.

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References

Bagnall, D.K., Shanahan, J.F., Flanders, A., Morgan, C.L.S., & Honeycutt, C.W. (2021). Soil health considerations for global food security. *Agronomy Journal* 2021; 1-9. https://doi.org/10.1002/agj2.20783

Barrera, V., Delgado, J.A., & Alwang, J.R. (2021) Conservation agriculture can help the South American Andean region achieve food security. *Agronomy Journal*, https://doi.org/10.1002/agj2.20879

Byamukama, E., Perez-Harnandez, O., & Yabwalo, D.N. (2021). Plant disease threats to food security in the Northern Great Plains of North America. *Agronomy Journal*, https://doi.org/10.1002/qgj2.20870.

Carr, P. M., Bell, J. M., Boss, D. L., Delaune, P., Eberly, J. O., Edwards, L., Fryer, H., Graham, C., Holman, J., Islam, M. A., Liebig, M., Miller, P. R., Obour, A. . . . Xue, Q. (2021). Annual forage impacts on dryland wheat farming in the Great Plains. *Agronomy Journal*, **113**, 1–25. https://doi.org/10.1002/agj2.20513

Clay, S.A. (2021). Near-term challenges for global agriculture: Herbicide-resistant weeds. *Agronomy Journal.* 2021; 1-10. https://doi.org/10.1002/agj2.20749

FAO (2009). How to feed the world in 2050. Food and Agriculture Organization. Executive Summary. http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf (Accessed 27 Sept. 2021)

Erickson, B. & Fausti, S. 2021. The role of precision agriculture in food security. *Agronomy Journal*

GFSI, (2020). Global Food Security Index 2020: Addressing structural inequalities to build strong and sustainable food systems. The Economist Intelligence unit . GFSI2020.pdf (nonews.co) (Accessed 27 Sept. 2021)

Ghimire, R., Adhikari, K.R., Chen, Z.-S., Shah, S.C., & Dahal K.R. (2012). Soil organic carbon sequestration as affected by tillage, crop residue, and nitrogen application in rice–wheat rotation system. *Paddy and Water Environment*, **10**, 95-102. DOI: 10.1007/s10333-011-0268-0.

Haarhoff, S.J., & Swanepoel, P.A. (2021). Current and future agronomic perspectives on rainfed soybean production systems in South Africa. *Agronomy Journal*, 2021; 1-34. https://doi.org/10.1002/agj2.20816

THIS ARTICLE IS PROTECTED BY COPYRIGHT. ALL RIGHTS RESERVED.

Accepted Article

IPCC, (2013). Summary for policymakers. In T. F. Stocker, D. Qin, G. Plattner, M. Tignor, S. K. Allen, J. Boschung, & A. Nauels (Eds.), Climate change 2013: The physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. New York: Cambridge University Press. AR5 Climate Change 2013: The Physical Science Basis — IPCC (Accessed 27 Sept. 2021)

Jeranyama, P. & C. Kennedy. 2021. Advancement in spring frost protection to sustain cranberry production in Massachusetts. *Agronomy Journal*

Joshi, D., Ghimire, R., Kharel, T., Mishra, U., & Clay, S.A. (2021). Conservation agriculture for food security and climate resilience in Nepal. *Agronomy Journal*, 2021; 1-22. https://doi.org/10.1002/agj2.20830.

Kwon, H., Liu, X., Xu, H., & Wang, M., (2021) Greenhouse gas mitigation strategies and opportunities for agriculture. *Agronomy Journal*, DOI: 10.1003/agj2.20844

Lamm, K., Randall, N.L., & Sherrier, J. (2021). Agriculture leaders identify critical issues facing crop production. *Agronomy Journal*, DOI: 10.1002/agj2.20835 Pg. 1-11

McLennon, E., Dari, B., Jha, G., Sihi, D., & Karnakala, V. (2021). Regenerative agriculture and integrative permaculture for sustainable and technology driven global food production and security. *Agronomy Journal*, 2021; 1-49. https://doi.org/10.1002/agj2.20814

Obour, A.K., Simon, L.M., Holman, J.D., Carr, P.M., Schipanski, M., Fonte, S., Ghimire, R., Nleya, T., & Blanco-Canqui. H. (2021). Cover crops to improve soil health in the North American Great Plains. *Agronomy Journal*, 2021; 1−15. https://doi.org/10.1002/agj2.2085

O'Brien, P., Kral-O'Brien, K., & Hatfield, J.L. (2021). Agronomic approach to understanding climate change and food security. *Agronomy Journal*, 2021; 1-11. https://doi.org/10.1002/agj2.20693.

Perry, J. N. (1995). *Regenerating Agriculture: Policies and Practice for Sustainability and Self-Reliance*. Joseph Henry Press. https://doi.org/https://doi.org/10.17226/493

Schwab, N., Schickhoff, U., & Fischer, E. (2015). Transition to agroforestry significantly improves soil quality: A case study in the central mid-hills of Nepal. *Agriculture, Ecosystems and Environment*, **205**, 57–69.

Sedebo, D.A., L, Gu-Cheng, K.A. Abebe, B. G. Etea, J. K. Ahiapka, N. Ouattara, A. Olounlade, & S. Frimpong. 2021. Smallholder farmers' climate change adaptation practices contribute to crop production efficiency in Southern Ethiopia. *Agronomy Journal*, https://doi.org/10.1002/agj2.20900

Smith, S., Nickson, T.E., & Challender, M. (2021). Germplasm exchange is critical to conservation of biodiversity and global food security. *Agronomy Journal*, **113**, 2969-2979

THIS ARTICLE IS PROTECTED BY COPYRIGHT. ALL RIGHTS RESERVED.

Accepted Article

Stewart, Z. P., Middendorf, B. J., & Prasad, P. V. V. (2018). SIToolKit.com. Feed the future innovation lab for collaborative research on sustainable intensification. Manhattan, KS: Kansas State University. Retrieved from https://www.sitoolkit.com. (Accessed 27 Sept. 2021).

United States Department of Agriculture – National Agricultural Statistics Service (USDA-NASS). (2019). State level data, Table 25. In 2017 Census. Field crops: 2017 and 2012 (Volume 1, pp. 498–514). Washington, DC: USDA NASS.

USDA (2021). United States Department of Agriculture Crop Production 2020 Summary. Online https://downloads.usda.library.cornell.edu/usda-esmis/files/k3569432s/w3764081j/5712n018r/cropan21.pdf (Accessed 27 Sept. 2021)

Wortmann, C.S., Bilgo, A., Kaizzi, C.K., Liben, F., Garba, M., Maman, N., Serme, I., & Stewart, Z.P. (2021a). Perennial grass ley rotations with annual crops in tropical Africa: A review. *Agronomy Journal*, 2021; 1-17. https://doi.org/10.1002/agj2.20634

Wortmann, C.S and Stewart, Z. P. (2021). Nutrient management for sustainable food crop intensification in African Tropical Savannas. *Agronomy Journal*, 2021: 1-11. https://doi.org/ 10.1002/agj2.20851.

Yaun, P., Wang, J., Chen, S., Guo, Y., & Cao, C. (2021). Certified rice–crayfish as an alternative farming modality in waterlogged land in the Jianghan Plain region of China. *Agronomy Journal*, 2021; 1-13. https://doi.org/10.1002/agj2.20694

Zahra, D., & Gambiza. (2019). Permaculture: Challenges and benefits in improving rural livelihoods in South Africa and Zimbabwe. *Sustainability*, **11**(8), 2219. https://doi.org/10.3390/su11082219

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