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Review

Dryland Food Security in Ethiopia: Current Status, Opportunities, and a Roadmap for the Future

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Abstract: Given the impact of COVID-19 and the desert locust plague, the Ethiopian food security issue has once again received widespread attention. Its food crisis requires comprehensive and systematic research to achieve the United Nations Sustainable Development Goal of zero hunger. This review discusses the current situation and the causes of food security in Ethiopia. We focus on the challenges in the food security assessment field. The article lists seven typical causes of food insecurity and three roots of food security in Ethiopia. Long-term food security assessment and a comprehensive understanding and manageability for food security causes are considered as the main existing research challenges. Climate-resilient management, water management, and long-term ecosystem network monitoring and data mining are suggested as potential roadmap for future research.

Keywords: drylands; Ethiopia; food security; resilience

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1. Introduction

Global drylands are expanding due to climate change [1], threatening global food security (FS), especially in Africa [2]. Eastern Africa has 328 million hectares of drylands, 6% of which is covered by crops; most crops are rained on, and irrigated land accounts for only 5 million hectares (22%) [3]. In Ethiopia, 75% of the landmass is categorized as dryland [4], the majority of which experiences high risks of land degradation, natural hazards, and water and food shortages [5]. Moreover, acidification is expected to lead to abrupt decays in plant productivity, soil fertility, and plant cover and richness at aridity values of 0.54, 0.7, and 0.8, respectively [6]. These abrupt decays of multiple ecosystems seriously threaten food security in Ethiopia. Under the pressures of natural conditions and global environmental changes, drylands are regarded as areas of major climatic hazard, limited in terms of long-term sustainable development [7]. In drylands, FS and resilience are adversely affected by environmental, economic, and social shocks [2,8]. Significant advances have been made in detecting dryland expansion and measuring food security. However, there are limited comprehensive analyses of droughts, including their evolution, complexity, social implications, and human vulnerability [9].

Thus, we review the literature related to food security status and introduce its causes in Ethiopia to present a complete and clear picture of food security. In addition, we synthesize previous research to find out the challenges and opportunities that currently exist in Ethiopian food security issues. Moreover, we hope to find out potential future research directions through combing the corresponding research to better assist the country's food security development.

2. Food Security Current Status

Food security is a flexible concept. Since the World Food Conference in 1974, there were more than 200 definitions and 450 indicators of food security created to describe food security issues [10], with the most authoritative and recognized definitions coming from the United Nations Food and Agriculture Organization (FAO). According to the definitions by FAO, the main goal of ensuring food security is to ensure that many people can buy and afford the basic food needed for survival and health at any time [11]. Therefore, ensuring food security has a three-dimensional goal, that is, to ensure maximum and stable food supply, to ensure that sufficient quantities of food are produced, and to ensure that those who need food can obtain food [6]. This article also discusses Ethiopia's food security issues under this definition.

The food security issue in Ethiopia is a long-standing issue. As early as the 1980s, it experienced the worst famine in history [12]. Since then, the country has been under a serious threat to food security. In Ethiopia, more than 33 million people suffer from chronic malnutrition and food insecurity, and the number of people suffering from hidden hunger may be even higher [13]. The Crop Prospects and Food Situation Report pointed out that more than 8.1 million Ethiopians are facing food shortages, including 400,000 children who are facing a severe food crisis in 2020, with 6% of these 8 million at 4 food security risks (emergency food security threats), 21% at Level 3 food security risk (in a food security crisis), 38% at a Level 2 food security risk (under food security pressure), and 34% at Level 1 food security risk (at a lower food security risk) [11]. From the point of view of space, the people suffering from hunger are mainly distributed in arid and semiarid regions, which nourish more than 13% of the country's population [10]. The report of FAO also pointed that the prolonged drought has affected the livelihoods of people in the arid areas of Eastern and Southern Ethiopia (Figure 1), with Oromia and Somalia provinces being the most severe areas of drought and famine [14]. For all the 8 million people in a food security crisis, 44% are in Oromia province, 22% are in Somali province, 13% are in Southern Nations, Nationalities, and Peoples' Region, 10% are in Amhara province, 5% are in Afar province, and 5% are in Tigray province [15].

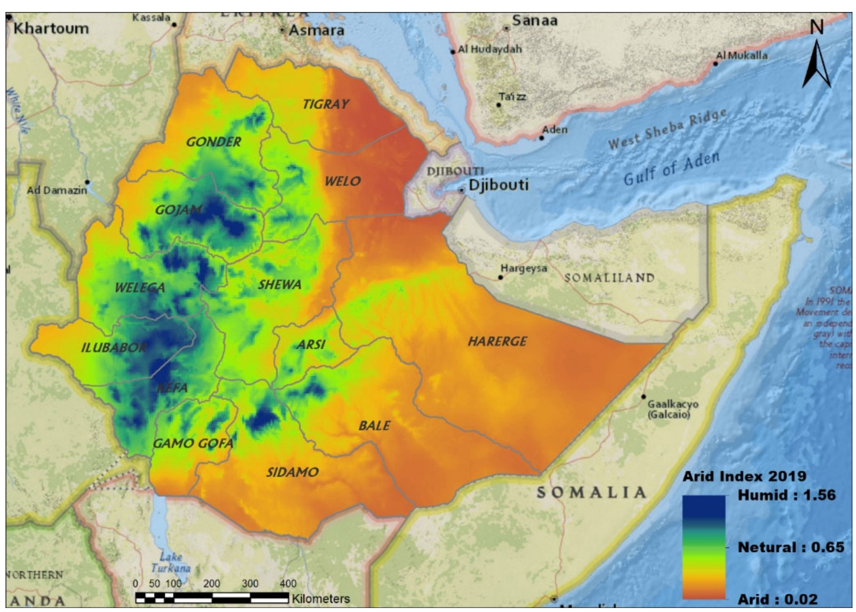

Figure 1. Aridity index distribution in Ethiopia in 2019. Note: Arid index was mapped by TerraClimate dataset using Google Earth Engine.

The causes of famine in Ethiopia are also diverse. In general, this is a result of the combined influence of natural and social factors. Although the increase in drought caused by global warming is a generally accepted cause, the influence of social factors has become more prominent in recent years [8]. After synthesizing the relevant literature, the following 7 main reasons are worthy of attention [6,13,16–21].

(1) Climate change and natural disasters: The proportion of rained agriculture in Ethiopia exceeds 90%, and the growth of crops is extremely dependent on natural conditions. With the intensification of global climate change and the increase of extreme disasters, the vulnerability of agricultural production has become more prominent [22].

(2) Backward agricultural infrastructure: Ethiopia's infrastructure construction in agricultural production is poor, and it lacks basic agricultural services such as irrigation, transportation, and storage. In the face of natural disasters and external factors, agriculture's coping ability is weak, and there is little room for adjustment [23].

(3) Country's agricultural science and technology being weak: Ethiopia's agricultural technology research and development are insufficient and lack field management measures, which makes it difficult to increase crop yields, and difficult to ensure stable agricultural production [24,25].

(4) Low degree of integration of agricultural market: Ethiopia's degree of agricultural integration is weak, and the level of interregional food trade is relatively low, which in turn restricts the expansion and integration of its agricultural market [26,27].

(5) Insufficient development of the private sector: Ethiopia has restricted the role of the private sector in agricultural production, but the low efficiency of government departments has further hindered the development of agricultural production [28].

(6) Political instability and social turmoil: Although Ethiopia has a relatively stable political environment in Africa, continued social conflicts, such as the Tigray crisis, have had a devastating impact on the local economic and social development, which in turn has affected the originally fragile agriculture serious obstacles to production [29].

(7) Unclear land property rights: The problem of unclear land property rights in Ethiopia is widespread, resulting in the lack of system and legal protection of land rights, which greatly reduces farmers' enthusiasm for production and is not conducive to the development of agricultural production [4,30].

All these reasons can be summed up as three main aspects to understand the root of food security in Ethiopia. The first and most fundamental matter is the continuous growth of the population. The total population of Ethiopia in 2017 was approximately 102.37 million; this is one of the root causes of food insecurity and is likely to continue to increase the pressure on Ethiopia to ensure a stable food supply [31]. The second reason can be attributed to the effects of drought. Famine caused by drought has become a norm in Ethiopia [32]. Periodic droughts in the past 60 years have caused serious crop yields and livestock losses in Ethiopia, which has led to many international food aids (Table 1). The last aspect of the problem is related to the political economy theory, which includes land degradation, outdated agricultural technology, weak agricultural infrastructure, and a single agricultural production structure [26,27]. In addition, unstable regimes and regional conflicts are also an important part of political and economic factors [29]. Political and economic factors have accounted for a large proportion of Ethiopia's acceptance of international food aid since 2017, although drought and floods are an ongoing topic.

Table 1. Food aid for Ethiopia since 2017.

Time	Reasons
Dec. 2016	Internal conflict/food prices
Feb., Apr., Sep. 2017	Extreme drought in Eastern Ethiopia
Aug. 2018	Conflict in Southwestern Ethiopia
Aug. 2018	Violent riots in Eastern Ethiopia
Sep. 2019	Severe drought in East Africa
Dec. 2019	East African floods
Feb. 2020	Conflict/disease outbreak/drought/flood
May. 2020	COVID-19/desert locust plague
Dec. 2020	Conflict in Tigray Region

3. Challenges and Opportunities

3.1. Challenges to Achieve Food Security Measuring and Resolving

The core of the current Ethiopian food security problem is how to conduct more accurate and timely monitoring, how to conduct systematic causes analysis, and how to conduct the coping strategy.

The first item is to conduct continuously and systematically long-term food security assessment supported by numerous ground data. There are two main ways to measure food insecurity in Ethiopia. The first is to assess the long-term food insecurity threat. This long-term food shortage is generally caused by insufficient production materials or economic poverty [33]. The second is a short-term food security threat, which is caused by fluctuations in food prices, food production, or food supply chain channels [34]. Research on food security assessment in Ethiopia generally takes the form of social surveys. Kahsay used the per capita daily calorie consumption as a measurement indicator to survey 150 households in Afar, Ethiopia. His findings showed that Ethiopian farmers in the rain-fed district are facing a higher level of food insecurity, with 72% of households being threatened by food insecurity [35]. Agidew evaluated the food insecurity status of farmers and herdsmen in Rael, Ethiopia, using 2100 calories per person per day as the minimum safety value of energy intake; it was found that more than 30% of the respondents only consume 1700 calories of food per person per day [36]. A study by Sani in Western Tigray, North Ethiopia, showed that more than half of households in arid areas did not get enough food, and the proportion of people threatened by food security in areas with frequent floods and droughts was significantly higher than in other areas [37]. These social surveys are meaningful, and they can truly and meticulously reflect the food supply situation at the household scale. However, this approach is still insufficient because it is difficult to continuously monitor long-term food threats, and it is even more difficult to trace the driving mechanism that causes food security problems. Ethiopia lacks specialized arable land data products to support its food security assessment [38]. It was not until the emergence of GFSAD African thematic arable land data in 2017 that this gap was filled [39]. Due to traffic accessibility and some policy restrictions, conducting remote sensing ground sample field surveys covering Ethiopia is a labor-intensive and costly task [40], and because of the lack of basic environmental data, it is also a labor-intensive and costly task [41], which limits the ability to conduct evaluations on a large scale through remote sensing methods.

The second challenge is to establish a comprehensive understanding and manageability for food security causes. Human–environment systems are coupled, dynamic, and co-adapting, and thus food security's structure, function, and interrelationships change over time [42]. Previous research divided Ethiopia's food security into four main pillars: food availability, access to food, food utilization, and stability of supply and access [43]. Ensuring food security is a systematic task because the determinants of each pillar significantly impact manageability [44]. Up until this point, the comprehensive understanding of food security is still rather weak according to Waldner [45]. Most of the current research focuses on the realization of a single goal. For example, some researchers aimed at improving crop varieties to increase food production [46], while some improved farmland management to ensure food security [47]. Some researchers want to improve food storage and transportation capacity after receipt to ensure better food supply [48], and some studies want to improve the stability of food production through the feedback mechanism under climate change [49]. However, single cause extermination is not enough; an explicit consideration of trade-offs among multiple aims is needed. Figure 2 shows a combination of the yield gap, social economy recovery, and a nature-based solution, as well as its interlinkages a system. Improving productivity, reducing drought risk, and achieving social, economic, and environmental sustainability are likely to improve the ability to ensure food supply. The strategy of targeting multiple wins where possible and balancing trade-offs that were not possible is a wise choice to achieve the zero hunger goal.

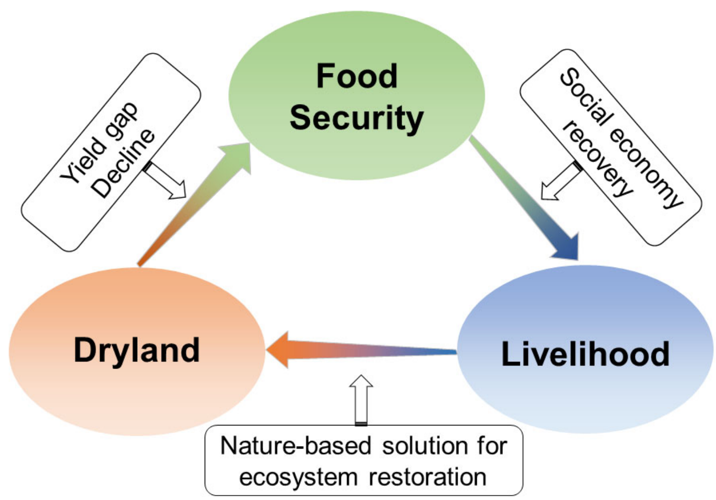

Figure 2. Interlinkages among drylands, food security, and livelihood resilience.

3.2. Opportunities to Meet the Gap

The newly launched science project—Global Dryland Ecosystem Programme (Global-DEP) provides us a new perspective to carry out the dryland food security researches. The Global-DEP project is intended to facilitate actionable interdisciplinary research on drylands [50]. The frameworks of G-DEP highlight the need for a number of elements, such as dryland social-ecological systems (SESs) drivers, structure and functions, ecosystem services, and management to achieve the SDGs' zero hunger goal. Ethiopian food security researches is similar to the logical sequence of in working process of dryland SESs, i.e., detecting famine driving forces, analyzing the linkages and interactions of food shortage, forming comprehensive management and policies against famine.

Research themes and priorities of G-DEP can bring us inspiration and reference to build a comprehensive understanding of the research on Ethiopian food issues (Figure 3). For example, the food security issue in Ethiopia can be divided into 4 main research directions. The first is food supply system dynamics and driving forces, the second is household and macroscopic mechanism or structure for food security, the third is food security adapting to a changing environment and society, and the final one is transforming the food supply system to meet sustainable livelihoods in drylands.

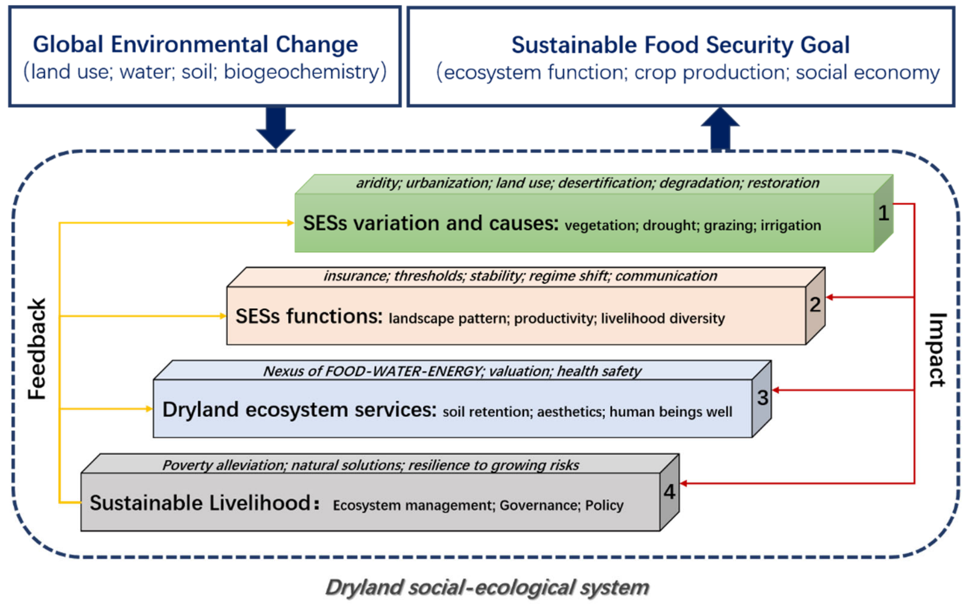

Figure 3. The synthetic conceptual framework of the G-DEP. Goals (Source: Modified by [50].)

4. Future Roadmap

There are emerging signs of the negative impact of COVID-19 on the agricultural food system, compounding ongoing problems of locust/fall armyworm infestations [51]. There is no single prescriptive adaptation solution to these challenges [52], and an integrated approach for rural development is required.

4.1. Climate-Resilient Management Experience from Similar Dryland Region

The dryland development paradigm (DDP), introduced in 2007, presented a highly influential framework for dryland development based on systems research [42]. Globally, drylands all face a host of urgent human and environmental challenges with far-reaching impacts. Thus, the successful climate-resilient management experience from different regions could be adapted in Ethiopian dryland food security practice. Mezquital Valley is a typical SES within the framework of the DDP. The sustainable water management strategies of Mezquital Valley empowered farmers to face upcoming external threats such as climate change [53], which is a good example for Ethiopia, where irrigation conditions are extremely scarce. The same successful experience also comes from China. Multiscale analyses on the ecosystem services of the Loess Plateau, a typical dryland region experiencing decades of ecological restoration, provide first-hand experience for ecological restoration at the inland degraded areas in Eastern Ethiopia [54]. Other experiences also included the Mediterranean [55] and Sicilian [56] regions.

4.2. In-Depth Data Mining of Long-Term Monitoring and Network Comparisons of Cross-Site Typical Ecosystems

Field observation data can be considered a kind of antenna for capturing food security statuses. The capability of in-depth data mining of long-term monitoring and the network comparisons of cross-site typical ecosystems play a decisive factor in correctly assessing and tracing food security in Ethiopia. The Chinese Ecosystem Research Network (CERN) is seen as a good example, whose practices can be modeled after in Ethiopian future works. CERN has accumulated a large amount of first-hand data for monitoring environmental changes, which is of great significance for the timely monitoring of drought and flood disasters [57]. In addition to the accumulation of observational data, data screening and mining are equally important. Various indicators for remote sensing monitoring of hunger are often biased and misleading [58], while cross-site typical ecosystems can reduce assessment errors caused by environmental differences [59].

4.3. Managing Water Supply and Demand in Dryland

Research pointed out that Ethiopia has a great groundwater potential varying from 2.6 to 13.5 billion m^3/year [60]. How to utilize underground water as an alternative source to strengthen irrigation activities and improve productivity is another potential direction against food security threats. Water management is important because climate changes, which are likely to occur during future decades, may have significant negative effects on the main water balance elements and maize yield [61]. Moreover, research also showed that Ethiopian farmers disfavored strategies related to water management, which can seriously waste the water potential of the area [49].

5. Conclusions

Drylands in Ethiopia are expanding, in turn threatening crop yields, which could impede the country's ability to meet the food needs of a growing population. This article reviewed Ethiopian food security's current status and synthesized the shortcomings of the current research field. Establishing a comprehensive understanding and manageability for food security causes and carrying out continuously and systematically long-term food security assessments supported by numerous ground data is a current emergency and challenge. We also pointed out the opportunities for follow-up research and the direction of focus. The interlinkages among drylands, FS, and resilience provide a broad understanding of adapted measures to dryland management and FS. The G-DEP and SESs concept brings new perspectives and opportunities in conducting food security research. Future research should pay high attention to climate-resilient management experience adaptation, long-term ecosystem network monitoring and data mining, and dryland water management. Under strong governmental commitment and steering on policy setting, investing in sustainable food production and scientific support for agriculture resilience can realize multiple benefits for Ethiopian FS.

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References

1. Yao, J.; Liu, H.; Huang, J.; Gao, Z.; Wang, G.; Li, D.; Yu, H.; Chen, X. Accelerated dryland expansion regulates future variability in dryland gross primary production. *Nat. Commun.* **2020,** 11, 1665.
2. Cervigni, R.; Morris, M. *Confronting Drought in Africa's Drylands: Opportunities for Enhancing Resilience*; The World Bank: Washington, DC, USA, 2016.

3. Food and Agriculture Organization (FAO). *Trees, Forests and Land Use in Drylands: The First Global Assessment—Full Report*; FAO: Rome, Italy, 2019.
4. Conijn, J. G.; Hermelink, M.; Deolu-Ajayi, A.; Kuiper, M. H.; Rossi Cervi, W. *Food System Challenges for Ethiopia*; Wageningen Research: Wageningen, The Netherlands, 2019.
5. Lu, N.; Wang, M.; Ning, B.; Yu, D.; Fu, B., Research advances in ecosystem services in drylands under global environmental changes. *Curr. Opin. Environ. Sustain.* **2018**, *33*, 92–98.
6. Berdugo, M.; Delgado-Baquerizo, M.; Soliveres, S.; Hernández-Clemente, R.; Zhao, Y.; Gaitán, J. J.; Gross, N.; Saiz, H.; Maire, V.; Lehmann, A.; et al. Global ecosystem thresholds driven by aridity. *Science* **2020,** *367*, 787.
7. Philip, S.; Kew, S. F.; Oldenborgh, G. J. v.; Otto, F.; O'Keefe, S.; Haustein, K.; King, A.; Zegeye, A.; Eshetu, Z.; Hailemariam, K.; et al. Attribution Analysis of the Ethiopian Drought of 2015. *J. Clim.* **2018,** *31*, 2465–2486.
8. IPCC. *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*; IPCC: Geneva, Switzerland, 2019.
9. Gebremeskel Haile, G.; Tang, Q.; Sun, S.; Huang, Z.; Zhang, X.; Liu, X. Droughts in East Africa: Causes, impacts and resilience. *Earth-Sci. Rev.* **2019,** *193*, 146–161.
10. Bezu, D. C. A review of factors affecting food security situation of Ethiopia: From the perspectives of FAD, economic and political economy theories. *Int. J. Agric. Innov. Res.* **2018,** *6*, 2319–2473.
11. FAO. *Crop Prospects and Food Situation—Quarterly Global Report—No.4*; FAO: Rome, Italy, 2020.
12. Webb, P.; Braun, J. v. *Famine and Food Security in Ethiopia: Lessons for Africa*; John Wiley & Sons Ltd.: Hoboken, NJ, USA, 1994.
13. Asrat, D.; Anteneh, A. Status of food insecurity in dryland areas of Ethiopia: A review. *Cogent Food Agric.* **2020**, *6*, 1853868.
14. FAO *Pastoralism in Africa's Drylands*; FAO: Rome, Italy, 2018.
15. Classification IFSP. *Acute Food Insecurity Analysis, World Food Program*; FAO: Rome, Italy, 2020.
16. FAO. *The Future of Livestock in Ethiopia. Opportunities and Challenges in the Face of Uncertainty*; FAO: Rome, Italy, 2019.
17. Liou, Y.-A.; Mulualem, M. G. Spatio–temporal Assessment of Drought in Ethiopia and the Impact of Recent Intense Droughts. *Remote Sens.* **2019**, *11,* 1828.
18. Seleshi, Y.; Zanke, U. Recent changes in rainfall and rainy days in Ethiopia. *Int. J. Clim.* **2004**, *24*, 973–983.
19. USDA. *Ethiopia 2008 Crop Assessment Travel Report;* US Department of Agriculture—Foreign Agricultural Service: Washington, DC, USA, 2019.
20. Zerfu, F.; Mektel, A.; Bogale, B. Land Use and Land Cover Dynamics in the North-Eastern Somali Rangelands of Eastern Ethiopia. *Int. J. Geosci.* **2019**, *10*, 811–832.
21. Tefera, N.; Demeke, M.; Kayitakire, F. *Building Sustainable Resilience for Food Security and Livelihood Dynamics: The Case of Rural Farming Households in Ethiopia*; European Commission: Ispra, Italy, 2017.
22. Mersha, E.; Boken, V.K. *Agricultural Drought in Ethiopia*; Oxford University Press: Oxford, UK, 2005.
23. Koo, J.; Thurlow, J.; ElDidi, H.; Ringler, C.; De Pinto, A. J. W. *DC: IFPRI, Building Resilience to Climate Shocks in Ethiopia*; IFPRI: Washington, DC, USA, 2019.
24. Salami, A.; Kamara, A. B.; Brixiova, Z. *Smallholder Agriculture in East Africa: Trends, Constraints and Opportunities*; African Development Bank: Tunis, Ghana, 2010.
25. Amsalu, A.; Adem, A. *Assessment of Climate Change-Induced Hazards, Impacts and Responses in the Southern Lowlands of Ethiopia*; Forum for Social Studies (FSS): Addis Abbe, Ethiopia, 2009.
26. Devereux, S.; Sussex, I. *Food Insecurity in Ethiopia;* Institute for Development Studie: Brighton, GreatBritain, 2000.
27. Abegaz, B. Escaping Ethiopia's poverty trap: the case for a second agrarian reform. *J. Mod. Afr. Stud.* **2004**, *24*, 313–342.
28. Gebreselassie, S. Intensification of smallholder agriculture in Ethiopia: Options and scenarios. In Proceedings of the Future Agricultures Consortium Meeting at the Institute of Development Studies, Brighton, GreatBritain, 1 March 2006.
29. Rettberg, S.; Beckmann, G.; Minah, M.; Schelchen, A. *Ethiopia's Arid and Semi-Arid Lowlands: Towards Inclusive and Sustainable Rural Transformation*; Albrecht Daniel Thaer-Institut für Agrar-und Gartenbauwissenschaften: Berlin, Germany, 2017.
30. FSIN. *Global Report on Food Security Crises: Joint Analysis for Better Decisions, Food Security Information Network*; FAO: Rome, Italy, 2019.
31. FAO. UNICEF; WFP; WHO. *The State of Food Security and Nutrition in the World 2020*; FAO: Roma, Italy, 2020.
32. Abera, D.; Kibret, K.; Beyene, S. Tempo-spatial land use/cover change in Zeway, Ketar and Bulbula sub-basins, Central Rift Valley of Ethiopia. *Lakes Reserv. Sci. Policy Manag. Sustain. Use* **2019,** *24*, 76–92.
33. FAO; UNICEF; WFP; WHO. *The State of Food Security and Nutrition in the World 2019*; FAO: Rome, Italy, 2019.
34. FAO. *Crop Prospects and Food Situation - Quarterly Global Report—No.1*; FAO: Rome, Italy, 2019.
35. Kahsay, S. T.; Reda, G. K.; Hailu, A. M. Food security status and its determinants in pastoral and agro-pastoral districts of Afar regional state, Ethiopia. *J. Sci. Technol. Innov. Dev.* **2020**, *12*, 333–341.
36. Agidew, A.-m. A.; Singh, K. Determinants of food insecurity in the rural farm households in South Wollo Zone of Ethiopia: the case of the Teleyayen sub-watershed. *Agric. Food Econ.* **2018**, *6*, 1–23.
37. Abraham, H.; Gizaw, S.; Urge, M. Begait goat production systems and breeding practices in Western Tigray, North Ethiopia. *Open J. Anim. Sci.* **2017,** *7*, 198.
38. Khatami, R.; Southworth, J.; Muir, C.; Caughlin, T.; Ayana, A. N.; Brown, D. G.; Liao, C.; Agrawal, A. Operational Large-Area Land-Cover Mapping: An Ethiopia Case Study. *Remote Sens.* **2020**, *12,* 954.

39. Xiong, J.; Thenkabail, P. S.; Gumma, M. K.; Teluguntla, P.; Poehnelt, J.; Congalton, R. G.; Yadav, K.; Thau, D. Automated cropland mapping of continental Africa using Google Earth Engine cloud computing. *Isprs J. Photogramm. Remote Sens.* **2017,** *126*, 225–244.
40. Zhong, L.; Gong, P.; Biging, G. S. Phenology-based Crop Classification Algorithm and its Implications on Agricultural Water Use Assessments in California’s Central Valley. *Photogramm. Eng. Remote Sens.* **2012,** *78*, 799–813.
41. Hao, P.; Tang, H.; Chen, Z.; Yu, L.; Wu, M. A sampling workflow based on unsupervised clusters and multi-temporal sample interpretation (UCMT) for cropland mapping. *Remote Sens. Lett.* **2018,** *9*, 952–961.
42. Stringer, L. C.; Reed, M. S.; Fleskens, L.; Thomas, R. J.; Le, Q. B.; Lala-Pritchard, T. A New Dryland Development Paradigm Grounded in Empirical Analysis of Dryland Systems Science. *Land Degrad. Dev.* **2017,** *28*, 1952–1961.
43. Al, W.; Orking, G.; Clima, O. *Climate Change and food Security: A Framework Document*; FAO: Italy, Rome, 2008.
44. UNDP. *Dealing with Complexity in Dryland Management in Ethiopia: An Integrated Approach;* UNDP: New York, NY, USA, 2014.
45. Waldner, F.; Bellemans, N.; Hochman, Z.; Newby, T.; de Abelleyra, D.; Verón, S. R.; Bartalev, S.; Lavreniuk, M.; Kussul, N.; Maire, G. L.; et al. Roadside collection of training data for cropland mapping is viable when environmental and management gradients are surveyed. *Int. J. Appl. Earth Obs. Geoinf.* **2019,** *80*, 82–93.
46. Shiferaw, B.; Kassie, M.; Jaleta, M.; Yirga, C. Adoption of improved wheat varieties and impacts on household food security in Ethiopia. *Food Policy* **2014,** *44*, 272–284.
47. Wossen, T.; Berger, T.; Di Falco, S. Social capital, risk preference and adoption of improved farm land management practices in Ethiopia. *Agric. Econ.* **2015,** *46*, 81–97.
48. Tesfaye, W.; Tirivayi, N. The impacts of postharvest storage innovations on food security and welfare in Ethiopia. *Food Policy* **2018,** *75*, 52–67.
49. Shikuku, K. M.; Winowiecki, L.; Twyman, J.; Eitzinger, A.; Perez, J. G.; Mwongera, C.; Läderach, P. Smallholder farmers' attitudes and determinants of adaptation to climate risks in East Africa. *Clim. Risk Manag.* **2017,** *16*, 234–245.
50. Fu, B.; Stafford-Smith, M.; Wang, Y.; Wu, B.; Yu, X.; Lv, N.; Ojima, D. S.; Lv, Y.; Fu, C.; Liu, Y.; et al. The Global-DEP conceptual framework—research on dryland ecosystems to promote sustainability. *Curr. Opin. Environ. Sustain.* **2021,** *48*, 17–28.
51. Union, F. a. A. *Measures for Supporting Domestic Markets during the COVID-19 Outbreak in Africa*; FAO: Rome, Italy, 2020.
52. Oguge, N. O. Chapter 18—Building resilience to drought among small-scale farmers in Eastern African drylands through rainwater harvesting: technological options and governance from a food–energy–water nexus perspective. In *Current Directions in Water Scarcity Research*. Mapedza, E.; Tsegai, D.; Bruntrup, M.; McLeman, R., Eds. Elsevier: Amsterdam, The Netherlands, 2019.
53. Durán-Álvarez, J. C.; Jiménez, B.; Rodríguez-Varela, M.; Prado, B. The Mezquital Valley from the perspective of the new Dryland Development Paradigm (DDP): present and future challenges to achieve sustainable development. *Curr. Opin. Environ. Sustain.* **2021**, *48*, 139–150.
54. Lü, Y.; Lü, D.; Feng, X.; Fu, B. Multi-scale analyses on the ecosystem services in the Chinese Loess Plateau and implications for dryland sustainability. *Curr. Opin. Environ. Sustain.* **2021**, *48*, 1–9.
55. Novara, A.; Gristina, L.; Sala, G.; Galati, A.; Crescimanno, M.; Cerdà, A.; Badalamenti, E.; La Mantia, T. Agricultural land abandonment in Mediterranean environment provides ecosystem services via soil carbon sequestration. *Sci. Total. Environ.* **2017**, *576*, 420–429.
56. Galati, A.; Crescimanno, M.; Gristina, L.; Keesstra, S.; Novara, A. Actual provision as an alternative criterion to improve the efficiency of payments for ecosystem services for C sequestration in semiarid vineyards. *Agric. Syst.* **2016**, *144*, 58–64.
57. Zhao, W.; Yu, X.; Xu, C. Social-ecological system management in drylands: experiences from Chinese Ecosystem Research Network. *Curr. Opin. Environ. Sustain.* **2021**, *48*, 93–102.
58. Teweldebirhan Tsige, D.; Uddameri, V.; Forghanparast, F.; Hernandez, E. A.; Ekwaro-Osire, S. Comparison of Meteorological- and Agriculture-Related Drought Indicators across Ethiopia. *Water* **2019**, *11*, 2218.
59. Smith, W. K.; Dannenberg, M. P.; Yan, D.; Herrmann, S.; Barnes, M. L.; Barron-Gafford, G. A.; Biederman, J. A.; Ferrenberg, S.; Fox, A. M.; Hudson, A.; et al. Remote sensing of dryland ecosystem structure and function: Progress, challenges, and opportunities. *Remote Sens. Environ.* **2019**, *233*, 111401.
60. Awlachew, S.; Erkossa, T.; Namara, R. *Irrigation Potential in Ethiopia Constraints and Opportunities for Enhancing the System*; International Water Management Institute: Addis Ababa, Ethiopia, 2010.
61. Muluneh, A. Impact of climate change on soil water balance, maize production, and potential adaptation measures in the Rift Valley drylands of Ethiopia. *J. Arid. Environ.* **2020**, *179*, 104195.