ADAPTATION IN AGRICULTURE TO A TEMPERATURE OVERSHOOT: CAN AGROECOLOGY BE A POTENTIAL STRATEGY?

KEY MESSAGES:

- There is little to no scientific literature on the adaptive capacity of agroecology under specific warming climate scenarios.
- A transformative adaptation approach, agroecology can be a viable adaptation strategy for agricultural production in a scenario of hotter global temperatures, because it improves resilience at the systems level.
- To increase resilience to hot temperatures, a system needs to – at the farm and landscape level – create agricultural systems that hold water, cool the microclimate, and reduce evapotranspiration. There are agroecological practices that do this.
- Agroecological strategies adapted by farmers in a range of environments, however, have adaptation limits; there are limits to resilience because of heat tolerance thresholds.
- Some literature suggests that, for future scenarios, agroecological strategies will need to incorporate technological innovations.

THE ISSUE

The world is heading towards an overshoot of the 2015 Paris Agreement 1.5°C target; current emissions trajectories are pointing towards 2°C and beyond, by mid-century.

Modeling from UNEP's Emissions Gap Report 2025: Off Target[1] found that global warming projections over the 21st century, based on full implementation of Nationally Determined Contributions (NDCs), are **2.3-2.5°C** while those based on current policies are **2.8°C**.

Compared to the present, climate-related risks for natural and human systems are higher for global warming of 1.5°C, and even higher at 2°C. Such high global temperatures will have an

[1] United Nations Environment Programme (2025). Emissions Gap Report 2025: Off target – Continued collective inaction puts global temperature goal at risk. Olhoff, A., chief editor; Lamb, W., Kuramochi, T., Rogelj, J., den Elzen, M., Christensen, J., Fransen, T., Pathak, M., Tong, D. (eds). Nairobi. https://doi.org/10.59117/20.500.11822/48854

impact on food security; more concerningly is that the risk of even "just" a 0.5°C rise in temperatures can have irreversible impacts for some ecosystems[2].

In 2023, the IPCC AR6 synthesis report moved the risk category to food security from "high" (in AR5) to "very high" (in AR6), at higher warming levels[3]; the WMO's State of the Global Climate Report[4] confirms 2015-2025 as the hottest 11 years on record.

So why are we worried? Because despite these science-backed projections and warnings, international commitments and strengthened climate governance, the goal of limiting global warming to below 2°C above preindustrial levels is at risk. Because agriculture and food security will be heavily impacted by high global temperatures. Because beyond impacts on agricultural productivity, systemic and compound threats are a major concern as impacts will be felt across areas (e.g. food, water, ecosystems, human health). Because some impacts, like ecosystem loss, become much harder - if not nearly impossible - to reverse as warming increases past 1.5°C**.** Because as temperatures warm beyond 2.0°C, uncertainties increase dramatically and adaptation becomes more difficult and much less effective. And finally, because the question of how agriculture will adapt to a global temperature overshoot has not been systematically addressed.

Among other things, high global temperatures will cause yield losses across all major staple crops, water scarcity and hydrological disruptions, heat stress to both animals and plants beyond physiological thresholds, pest and disease pressures, soil degradation, disruption of fisheries. Adaptation is considered a key factor that will shape the future severity of climate change impacts on food production[5].

PURPOSE

The conversation on adaptation options to a temperature overshoot needs to be opened; global debates on preparing for a much hotter world and its impacts on all four pillars of food security[6] – need to start. Sticky questions like: "what are the necessary actions that global communities, institutions and governments will need to take to adapt to a temperature overshoot?" need to be answered.

Here, we open the debate by focusing on agroecology as a holistic, promising, adaptation option, to address the question: is there evidence of agroecology being an effective adaptation strategy to temperature overshoot, for agricultural production?

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[2] IPCC. (2018). Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Masson-Delmotte, V., Zhai, P., Pörtner, H-O., Roberts, D., Skea, J., Shukla, P.R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., Connors, S., Matthews, J.B.R., Chen, Y., Zhou, X., Gomis, M.I., Lonnoy, E., Maycock, T., Tignor, M. & Waterfield, T. (eds.). Cambridge University Press, Cambridge, UK and New York, NY, USA, 616 pp. https://doi.org/ 10.1017/9781009157940
[3] IPCC. (2023). Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Core Writing Team, Lee, H. & Romero, J. (eds.). IPCC. Geneva. Switzerland. 184 pp. doi: 10.59327/IPCC/AR6-9789291691647
[4] World Meteorological Organization (WMO). *State of the Global Climate 2025*. (WMO-No. 1342). Geneva, 2026. ISBN: 978-92-63-11299-7. https://doi .org/10 .59327/WMO/S/CRI/SOC1
[5] Altieri, M.A., Nicholls, C.I., Henao, A. et al. Agroecology and the design of climate change-resilient farming systems. Agron. Sustain. Dev. 35, 869–890 (2015). https://doi.org/10.1007/s13593-015-0285-2
[6] Availability, access, utilization, stability.

For the preparation of this report, we search for scientific literature on agroecology as an adaptation strategy to respond to climate change impacts under "climate overshoot" conditions (average global warming beyond 1.5°C); and, for those papers that discuss agroecology as an adaptation strategy under the conditions of "climate overshoot", to summarize the agroecological practices and/or approaches that are presented in these papers. This will be supported by focused conversation with relevant experts[7] in the agroecology community.

WHY AGROECOLOGY?

Agroecology has gained significant attention as a promising approach to address climate-change related challenges, in the context of climate change adaptation, and to promote sustainable and resilient agricultural systems[8,9,10,11,12,13.]. Already in 2019, the IPCC Special Report on Climate Change and Land stated that "increasing resilience of the food systems through agroecology and diversification is an effective way to achieve climate change adaptation". As an approach with agronomic, economic and social benefits, there is robust evidence (although for the IPCC, medium agreement[14]) showing the positive impacts of agroecology on resilience, sustained yields, and increased livelihoods[15].

One reason for this can be that "agroecology" has multiple definitions, and spans a range of interpretations – from disciplines, approaches and practices, to dimensions[16]. The definition of agroecology varies according to the concerns and priorities of different institutions or countries.

"Agroecology" began as a scientific discipline to deal with crop production and protection, but has evolved to mean either a scientific discipline, agricultural practice or political or social movement. The scale of "agroecological approaches" can also vary, according to where is it practiced, from

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[7] Dr Altieri, M.A. Professor Emeritus University of California Berkley.
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Dr Oliver Oliveros. Coordinator of Agroecology Coalition and Head of Agroecology Coalition Secretariat.

[8] Zenda, M., & Rudolph, M. (2024). A Systematic Review of Agroecology Strategies for Adapting to Climate Change Impacts on Smallholder Crop Farmers' Livelihoods in South Africa. Climate, 12(3), 33. https://doi.org/10.3390/cli12030033

[9] Ali, Ibrahim. (2024). The Role of Agroecology in Food Security in Developing Countries. Conference Paper. 4th International Conference on Engineering, Natural and Social Sciences. Konya, Turkiye

10 Holt-Giménez, E., Shattuck, A., & Van Lammeren, I. (2021). Thresholds of resistance: agroecology, resilience and the agrarian question. The Journal of Peasant Studies, 48(4), 715–733. https://doi.org/10.1080/03066150.2020.1847090.

[11] Diacono, M. et al. (2016). Combined Agro-ecological Strategies for Adaptation of Organic Horticultural Systems to Climate Change in Mediterranean Environment, Italian Journal of Agronomy, 11(2). https://doi.org/10.4081/ija.2016.730.

[12] Altieri, M.A., Nicholls, C.I., Henao, A. et al. Agroecology and the design of climate change-resilient farming systems. Agron. Sustain. Dev. 35, 869–890 (2015). https://doi.org/10.1007/s13593-015-0285-2

[13] Sinclair, F. et al. (2019). The Contribution of Agroecological Approaches to Realizing Climate-Resilient Agriculture. Rotterdam and Washington, D.C. Global Commission on Adaptation.

[14] IPCC. (2023). Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Core Writing Team, Lee, H. & Romero, J. (eds.). IPCC. Geneva. Switzerland. 184 pp. doi: 10.59327/IPCC/AR6-9789291691647

[15] IPES Food. Climate change, adaptation and the potential of agroecology. https://ipes-food.org/wp-content/uploads/2024/03/AgroecologyClimateInfo.pdf

[16] Gliessman, S. (2018). Defining Agroecology. *Agroecology and Sustainable Food Systems*, *42*(6), 599–600. https://doi.org/10.1080/21683565.2018.1432329

(1) investigations at plot and field scales; (2) investigations at the agroecosystem and farm scales; to (3) investigations covering the whole food system[17].

In addition to having multiple definitions, in a more recent evolution, agroecology is characterized by 13 principles (HLPE)[18] and ten elements (FAO)[19]. The 13 principles consider a focus beyond just farming systems, to address agrifood systems and "embrace a transdisciplinary outlook". They are grouped into three operational principles: improve resource efficiency (recycling; input reduction), strengthen resilience (soil health; animal health; biodiversity; synergy; economic diversification) and secure social equity/responsibility (co-creation of knowledge; social values and diets; fairness; connectivity; land and natural resource governance; participation)[20].

An agroecological approach is defined by FAO as "a holistic and integrated approach that applies ecological and social concepts and principles to the design and management of sustainable agriculture and food systems". The ten elements are: diversity; co-creation and sharing of knowledge; synergies; efficiency; recycling; resilience; human and social values; culture and food traditions; responsible governance; and circular and solidarity economy[21].

Agroecology has environmental, economic and social benefits. Examples of environmental benefits can include enhanced biodiversity, reduced pollution, and improved soil health and fertility. Examples of economic benefits can include diversified sources of income, lower external input costs, and shorter supply chains. Examples of social benefits are that small farmers and rural communities are empowered, food sovereignty is strengthened, and that traditional knowledge and farming practices are preserved.

Agroecology works on principles, interconnections and systems – it is *not* sectoral[22]. Following on this, from the perspective of production, there is no pre-defined list of agroecological practices – rather, there is a wide range of practices in the literature which fall under the ten elements. In other words, practices that support the implementation of the ten elements. Agroecological farming emphasizes diversification, soil health, ecological pest control, agroforestry, water conservation, biodiversity management, crop-livestock integration, and resource recycling.

Just some examples of some specific practices include crop diversification, crop rotation, intercropping, mulching, biofertilizers, no-till farming, terracing, contour farming, agroforestry, silvopastoral, windbreaks, biopesticides, push-pull systems, drip irrigation, water harvesting, hedgerows, ecological corridors, pollinator habitat, crop-livestock system, rotational grazing, participatory plant breeding, and nutrient cycling systems.

As an environmentally, socially and economically sustainable agricultural approach, agroecology can be considered a potential adaptation strategy for temperature overshoot because it

[17] FAO. Family Farming Knowledge Platform. https://www.fao.org/family-farming/detail/en/c/386189/#:~:text=The%20term%20%22agroecology%22%20can%20have%20multiple%20meanings:,emergence%20of%20agroecological%20movements%20in%20the%201990s.
[18] 2019 High-Level Panel of Experts on Food Security and Nutrition (HLPE).
[19] Approved at FAO's 163 session of the Council on 2-6 December 2019.
[20] HLPE. 2019. Agroecological and other innovative approaches for sustainable agriculture and food systems that enhance food security and nutrition. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome. https://www.fao.org/fileadmin/user_upload/hlpe/hlpe_documents/HLPE_Reports/HLPE-Report-14_EN.pdf
[21] FAO. (2018). The 10 Elements of Agroecology. Guiding the transition to sustainable food and agricultural systems. Rome, Italy. https://openknowledge.fao.org/handle/20.500.14283/i9037en
[22] C. Batello. Personal communication. March, 2026.

encompasses a range of ecologically sustainable agricultural practices, and is ecosystem-based. There is evidence that each of the individual practices – either implemented alone or together with other practices in a given space – can increase the resilience of agroecosystems to climate change. There are agroecological practices that can support farmers in adapting to rising temperatures.

The majority of empirical evidence for this comes from smallholder farming systems, especially in Africa, Asia and Latin America[23,24,25,26], but there is also evidence at the landscape level, with the case of natural farming in Andhra Pradesh standing out as a well-documented, state-wide, agroecological transformation[27],[28],[29].

AGROECOLOGY'S POTENTIAL

With the exception of one review conducted for the Mediterranean region addressing climate scenarios from 1.5ºC-3ºC[30], there are no widely cited experiments or models that explicitly test agroecological systems under specific climate scenarios such as +1.5 °C, +2 °C, or +3 °C global warming. There is however evidence of agroecological advantages in addressing most of the key climate stressors agriculture faces at +1.5°C - particularly drought, extreme weather, biodiversity loss, soil degradation, and pest pressures.

Hence - while there is limited information in the scientific literature for *specifically* saying that agroecology is a strategy that can be implemented to adapt to temperatures beyond 1.5ºC, there is evidence that shows that agroecology has potential for helping farming systems adapt to higher temperatures, primarily through practices that increase resilience. Agroecology is not a one-size fits all solution, rather, it is an evolving adaptation of different elements that makes the *system* resilient[31].

Agroecology is a broader resilience approach, but under the umbrella of agroecology and always bearing in mind context-specificities, there are a number of practices that directly contribute to adaptation to higher temperatures. The geographical areas where higher temperatures will be felt the most are in arid and semi-arid areas, and Mediterranean areas which are becoming much drier. This means that there will be higher evapotranspiration rates through greater water loss from plants and soils. Practices that deal with excessively high temperatures are through: (a)

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[23] Leippert, F., Darmaun, M., Bernoux, M. and Mpheshea, M. (2020). *The potential of agroecology to build climate-resilient livelihoods and food systems.* Rome. FAO and Biovision. https://doi.org/10.4060/cb0438en
[24] Q., Alejandra, A., & Nadine, A. (2024). Evidence of agroecology's contribution to mitigation, adaptation, and resilience under climate variability and change in Latin America. *Agroecology and Sustainable Food Systems*, *48*(2), 228–252. https://doi.org/10.1080/21683565.2023.2273835
[25] Altieri, M.A., Nicholls, C.I. The adaptation and mitigation potential of traditional agriculture in a changing climate. *Climatic Change* 140, 33–45 (2017). https://doi.org/10.1007/s10584-013-0909-y
[26] Snapp S, Kebede Y, Wollenberg E, Dittmer KM, Brickman S, Egler C, Shelton S. 2021. Agroecology and climate change rapid evidence review: Performance of agroecological approaches in low- and middle- income countries. Wageningen, the Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).
[27] Oliveros, O. Personal Communication. March 2026.
[28] GIST Impact Report. (2023). "Natural Farming Through a Wide-Angle Lens: True Cost Accounting Study of Community Managed Natural Farming in Andhra Pradesh, India." GIST Impact, Switzerland and India.
[29] https://www.cirad.fr/en/press-area/press-releases/2024/agroeco2050-foresight-study
[30] Eduardo Aguilera, Cipriano Díaz-Gaona, Raquel García-Laureano, Carolina Reyes-Palomo, Gloria I. Guzmán, Livia Ortolani, Manuel Sánchez-Rodríguez, Vicente Rodríguez-Estévez. (2020).
Agroecology for adaptation to climate change and resource depletion in the Mediterranean region. A review. *Agricultural Systems,* 181. https://doi.org/10.1016/j.agsy.2020.102809.
[31] C. Batello. Personal communication March, 2026.

microclimate regulation by providing shade; (b) increasing water retention by decreasing water loss from soils and plants, and (c) biodiversity enhancement. This is supported by a review which found that there is little evidence on how to buffer effects of extreme weather events other than through agroforestry and crop diversification[32].

For example, practices such as mulching, planting cover crops and encouraging high soil organic matter[33] help cool soil and retain moisture[34,35]. Crop heat stress can be lowered by creating shade and promoting cooler microclimates through practices such as agroforestry[36] or planting windbreaks[37]. As hotter and drier weather conditions can impact crop production, improving water efficiency is important: rainwater harvesting, drip irrigation, soil organic management are some examples of practices that can do this.

Microclimate regulation.

Trees in crop fields contribute to improving soil fertility, soil health (beneficial soil organisms are more abundant in crop fields with trees), erosion control, water retention, and shade provision[38]. Increasing vegetative cover on land – and in particular planting trees - decreases temperatures in the microclimate, by providing shade[39].

Classic examples are agroforestry practices, planting shade trees. Shade trees are planted to mitigate higher temperatures for crops, from coffee to wheat and rice. Coffee agroforestry in Indonesia showed that shade trees reduce temperatures experienced by coffee plants, by up to 2°C[40]. In Niger's Farmer-Managed Natural Regeneration programme, farmers planted native nitrogen-fixating trees alongside crops, which provided multiple ecological benefits including providing shade, which reduced evaporation. This programme started in the 1980's with beneficial ecosystemic outcomes but also for farmer livelihoods. Since then, the programme led to the reconstitution of vegetation on about five million hectares of farmland, resulting in a transformation of the environment; this is also an example of adaptation at the landscape level[41]. One meta-analysis showed that cocoa agroforestry contributed to adaptation by lowering mean temperatures and buffering temperature extremes[42].

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[32] Dittmer, K.M., Rose, S., Snapp, S.S. *et al.* Agroecology Can Promote Climate Change Adaptation Outcomes Without Compromising Yield In Smallholder Systems. *Environmental Management* 72, 333–342 (2023). https://doi.org/10.1007/s00267-023-01816-x
[33] Lal, R. (2020). Soil organic matter and water retention. *Agronomy Journal*, *112*(5), 3265-3277.
[34] Castro-Bedrinana, J., Alomia-Lucero, J., Chirinos-Peinado, D. & Huari-Salazar, Y. (2026).
Nature-based strategies for heat mitigation: shade index modeling of cover crops in rooftop agriculture. Nature-Based Solutions, 9. https://doi.org/10.1016/j.nbsj.2026.100315.
[35] Altieri, M.A. & Nicholls, C.I. (2017). The adaptation and mitigation potential of traditional agriculture in a changing climate. *Climatic Change.* 140 (1). No 4, 33-45.
[36] Lin, B.B. (2007). Agroforestry management as an adaptive strategy against potential microclimate extremes in coffee agriculture. *Agricultural and Forest Meteorology.* https://doi.org/10.1016/j.agrformet.2006.12.009
[37] https://agroforestry.org/the-overstory/37-overstory-220-adapting-to-climate-change?utm_source=chatgpt.com
[38] Sinclair, F. et al. (2019). The Contribution of Agroecological Approaches to Realizing Climate-Resilient Agriculture. Rotterdam and Washington, D.C. Global Commission on Adaptation.
[39] Campbell, E. (2011). The agroecosystem role in climate change mitigation and adaptation. *Carbon Management*, *2*(5), 501–503. https://doi.org/10.4155/cmt.11.51
[40] Jaramillo, J. et al. (2011). Some like it hot: The influence and implications of climate change on coffee berry borer. PLOS ONE 6(4):e24528; Bunn, C. et al. (2015). Subnational assessment of climate change impacts on the suitability of coffee production in Indonesia. Climatic Change 132:211–224; Jha, S. et al. (2014). Shade coffee: Update on a disappearing refuge for biodiversity. BioScience 64(5):416–428.
[41] Abasse, T. et al. (2023). Farmer managed natural regeneration in Niger: the state of knowledge. Tropenbos International, Ede, the Netherlands.
[42] Niether, W. et al. (2020). Cocoa agroforestry systems versus monocultures: a multi-dimensional meta-analysis. *Environ. Res. Lett.* 15. 104085. https://doi.org/10.1088/1748-9326/abb053

At field scale, shade trees buffer rising temperatures to stabilize crops yields, and increasing the yield of food staples by lowering daytime temperatures and reducing heat stress. Shade is increasingly important because tree shade buffers high temperatures - and can, for example, prolong grain filling in cereals and bean yield (and quality) in coffee. In Ethiopia, wheat yields in were 26– 86% higher under *Faidherbia albida* trees than in monocultures, with proportionally larger effects in low yielding (drier) years[43]. In Peru, during interviews conducted with farmers and researchers for a study on perceptions of agroecology's contributions to climate change adaptation and mitigation, responders said that agroecological systems tend to manifest lower temperatures than those recorded in surrounding conventional production farms – this difference was attributed to having "created a diversified landscape with different types of trees and cover that generate shade and result in a more temperate microclimate". For the same study, two farmers in Colombia claimed to have, several times, measured temperatures and registering up to 10°C less on their farm than on nearby farms[44].

Shade in silvopastoral systems addresses heat thresholds for animals; heat stress causes health issues for animals and decreased milk production In Colombia, where 5ºC lower temperatures were recorded because of silvopastoral systems, it was found that milk production losses were less and animals required less antibiotics[45]. Silvopastoral systems also increase nutritional diversity for animals (as opposed to open pasture systems). Both the literature review and stakeholder testimonies in the 2024 study in Latin America highlighted that crop and animal diversification and integration of trees into farming systems were central to resilience in the context of climate change[46].

Increasing water retention.

Among other effects, extreme temperatures will increase the frequency and intensity of drought. Agroecology allows farmers to adapt to the impacts of drought by increasing soil organic matter, water harvesting, and, as discussed further below, using drought-tolerant plant varieties. Drought can be managed by increasing resilience to water stress, through multiple mechanisms that operate synergistically.

The water holding capacity of soils can be increased by intercropping and organic matter additions; soils with higher organic carbon content retain significantly more plant-available water per unit of rainfall[47]. Mulching and increasing ground cover (planting cover crops) increases soil organic matter (SOM) – for every 1% increase in SOM, water holding capacity increases to

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[43] Sinclair, F. et al. (2019). The Contribution of Agroecological Approaches to Realizing Climate-Resilient Agriculture. Rotterdam and Washington, D.C. Global Commission on Adaptation.

[44] Q., Alejandra, A., & Nadine, A. (2024). Evidence of agroecology's contribution to mitigation, adaptation, and resilience under climate variability and change in Latin America. *Agroecology and Sustainable Food Systems*, *48*(2), 228–252. https://doi.org/10.1080/21683565.2023.2273835

[45] Altieri, M.A. Personal communication. March 2026.

[46] Q., Alejandra, A., & Nadine, A. (2024). Evidence of agroecology's contribution to mitigation, adaptation, and resilience under climate variability and change in Latin America. *Agroecology and Sustainable Food Systems*, *48*(2), 228–252. https://doi.org/10.1080/21683565.2023.2273835

[47] Minasny, B. et al. (2017). Soil carbon 4 per mille. Geoderma 292:59–86; Lal, R. (2004). Soil Carbon Sequestration Impacts on Global Climate Change and Food Security. Science 304(5677):1623–1627.

175,000 l/ha. Organic matter will enhance microbial activity which in turn will induce resistance to drought[48].

Traditional water harvesting techniques are agroecological adaptation practices that have shown to increase water infiltration. An example is zaï pits in Burkina Faso's semi-arid regions, which capture rainwater, concentrate organic matter, improve water infiltration and improve drought resilience[49,50].

A key aspect of an agroecological approach to increasing water retention is the need to work at the landscape or watershed level, through ecosystem-based practices but also through a high level of community participation. It is important to slow down water loss, for example through swales on hilly landscapes, but also on flatter agricultural land. In other words, managing green water cycles across landscapes, creating agricultural ecosystems that hold and transpire water rather than allowing it to run off[51].

Designing a landscape to keep (micro)temperatures down, is an objective of the Village Homes initiative in Davis, California where, in a 60-acre development, water is directed into integrated landscapes to promote healthy, moist soil that in turn supports dense vegetation and mature trees that cool the air and buildings. This initiative reports that over the past 50 years, "Village Homes' microclimate runs 10-15°F cooler than surrounding conventional Davis neighborhoods during summer afternoons"[52]. While this is not strictly agriculture, it is an example of adapting to high temperatures by managing landscapes and green water cycles.

However, it is essential to acknowledge the limits of increasing water retention at both plant and soil points of entry. In prolonged severe drought — which will become more common above 2°C — even well-designed agroecological systems eventually fail. In the absence of irrigation, it does not matter how much organic matter is added to the soil or how much soil is covered with mulch, because most crops will not withstand such prolonged water stress.

Biodiversity enhancement.

The more biodiversity (diversity, richness) in a farm or landscape, the more options a farmer has to improve agroecosystem resilience to warmer temperatures[53]. Biodiversity can be enhanced in many different ways. Crop diversification is one way[54,55,56] - heat-induced crop failure risks can be reduced[57] by increasing biodiversity, or planting drought-tolerant and heat-resistant plant

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[48] M. Altieri. Personal Communications, March 2026.

[49] https://www.ideassonline.org/public/pdf/ZAI-ENG.pdf

[50] R. Zougmoré, Z. Zida, & N.F. Kambou. (2003) Role of nutrient amendments in the success of half-moon soil and water conservation practice in semiarid Burkina Faso, Soil and Tillage Research, 71(2). https://doi.org/10.1016/S0167-1987(03)00050-3.

[51] B. Gemmill-Herren. Personal communication, March 2026.

[52] https://lali.teachable.com/p/architecture-of-cooling-oases?mc_cid=92952165da&mc_eid=5fa85a3931

[53] Altieri, M.A., Nicholls, C.I., Henao, A. *et al.* (2015). Agroecology and the design of climate change-resilient farming systems. *Agron. Sustain. Dev.* **35**, 869–890. https://doi.org/10.1007/s13593-015-0285-2

[54] Leippert, F., Darmaun, M., Bernoux, M. and Mpheshea, M. (2020). *The potential of agroecology to build climate-resilient livelihoods and food systems.* Rome. FAO and Biovision. https://doi.org/10.4060/cb0438en

[55] Altieri, M.A., Nicholls, C.I., Henao, A. *et al.* (2015). Agroecology and the design of climate change-resilient farming systems. *Agron. Sustain. Dev.* **35**, 869–890. https://doi.org/10.1007/s13593-015-0285-2

[56] Snapp S, Kebede Y, Wollenberg E, Dittmer KM, Brickman S, Egler C, Shelton S. 2021. Agroecology and climate change rapid evidence review: Performance of agroecological approaches in low- and middle- income countries. Wageningen, the Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

[57] Sanchez, A.C. et al. (2022). Diversified farming systems are more productive and profitable than monocultures. Ecological Economics 191:107226. https://doi.org/10.1016/j.ecolecon.2021.107226

varieties to mitigate the impacts of higher temperatures[58]. Crops and trees selection is also important – for example, C3 crops will suffer more from extreme heat, while C4 crops will fare better. Perennial crops are more resistant than annuals as they have deeper roots; annual systems collapse much earlier; also, one study of the biophysical effects of perennial agriculture systems finds substantial climate cooling from increased evaporation[59]. Fruit trees such as pomegranates, olives, loquats, figs and apricots are more resilient than, say, apples or grapes. Almonds are also more resistant.

A review of agroecological strategies implemented by smallholder farms in South Africa found that indigenous crop varieties are often well-adapted to local conditions and were used[60].

Planting hedgerows can provide fodder and habitat for pollinators, encouraging insect pollinators to provide crop pollination services. Using native plant species that bloom at different times can provide a continuous food source[61]. Having said that – a very real threat of a temperature overshoot is that the synchronicity of plant/pollinator flowering/pollination times will be disrupted. CO_2 will increase, increasing pollen production – but pollen production will occur earlier (late winter/early spring). Furthermore, the quality of the pollen will decrease, as high temperatures will impact amino acids and sugar content[62].

Integrated systems such as agroforestry or silvopastoral systems can also improve biodiversity, as well as having other benefits for resilience to extreme temperatures. Integrating trees with crops and livestock, for example, can enhance on-farm biodiversity by 25–40% while improving soil organic carbon by an average of 15% over two decades[63].

Summary of meta- evidence.

This section is a brief compilation of most recent, major meta-analyses or reviews of work on agroecology and adaptation.

When, at the landscape or watershed level, agricultural ecosystems are created to include agroecological approaches, greater adaptation (and also mitigation) benefits have been recorded. Evidence suggests that increasing the diversification of agricultural systems at the field and landscape level, and enhancing soil organic matter and biological activity, are key strategies to improve the resilience of agricultural systems to climate variability[64].

A 2023 study[65] reviewed evidence of the potential of agroecology as a transformative approach, as an adaptation (and mitigation) strategy, and as a strategy that meets societal goals including

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[58] Kumar, A., Muthuramalingam, P., Kumar, R., Tiwari, S., Verma, L., Park, S., & Shin, H. (2025). Adapting Crops to Rising Temperatures: Understanding Heat Stress and Plant Resilience Mechanisms. *International Journal of Molecular Sciences,* 26(21), 10426. https://doi.org/10.3390/ijms262110426

[59] Georgescu M, Lobell DB, Field CB. Direct climate effects of perennial bioenergy crops in the United States. *Proc.Natl Acad. Sci.* DOI: 10.1073/pnas.1008779108 (2011).

[60] Zenda, M., & Rudolph, M. (2024). A Systematic Review of Agroecology Strategies for Adapting to Climate Change Impacts on Smallholder Crop Farmers' Livelihoods in South Africa. *Climate*, *12*(3), 33. https://doi.org/10.3390/cli12030033

[61] FAO. (2020). Towards sustainable crop pollination services – Measures at field, farm and landscape scales. Rome. https://doi.org/10.4060/ca8965en

[62] Altieri, M. personal communication March 2026.

[63] Quijas, S. et al. (2021). The role of biodiversity in advancing food security. Global Food Security 28:100479; Guo, L.B. & Gifford, R.M. (2002). Soil carbon stocks and land use change: a meta analysis. Global Change Biology 8(4):345–360.

[64] AltieriM. A.NichollsC. I.HenaoA.LanaM. A. (2015). Agroecology and the design of climate change-resilient farming systems. *Agron. Sustain. Dev.*35, 869–890. doi: 10.1007/s13593-015-0285-2

[65] Kerr, R. *et al.* (2023). Agroecology as a transformative approach to tackle climatic, food, and ecosystemic crises. *Current Opinion in Environmental Sustainability*, 62. https://doi.org/10.1016/j.cosust.2023.101275.

food security and nutrition. It found that agroecology improves adaptation outcomes, such as water regulation and nutrient cycling. Another 2023 review found that although data on climate change mitigation and adaptation are not widely tracked for agroecological interventions, such interventions promote significant positive climate change adaptation outcomes with no or minimal trade-offs for productivity and income[66].

A 2021 study found evidence suggesting that agroecology provides more climate change adaptation (and mitigation) than conventional, higher- input agricultural development in Lower- and Middle-Income Countries (LMICs) by emphasising locally relevant solutions, participatory processes and co-creation of knowledge as core values. The agroecological approach with the strongest body of evidence for impacts on climate change adaptation was farm diversification (positive impacts on crop yield, pollination, pest control, nutrient cycling, water regulation and soil fertility) [67]. A 2024 review of agroecology strategies and adaptation in South Africa reported that many smallholder crop farmers used a variety of agroecology strategies to adapt to climate change impacts, including the use of indigenous and drought-tolerant crop varieties, conservation agriculture practices, intercropping, agroforestry, crop management and water management techniques. The studies show that these practices can have many benefits, including increasing crop resilience, improving soil fertility and using water more efficiently – potentially leading to improved livelihoods[68].

Lastly, a 2020 review of 34 quantitative meta-analyses found that the most solid evidence on strengthening climate resilience through increased adaptive capacity and reduced vulnerability is through improved soil health, high levels of agrobiodiversity and high diversification[69].

AGROECOLOGY'S (BIOPHYSICAL) LIMITATIONS

Overall, agroecology contributes to adaptation because of its ability to improve resilience to climate change at the ecosystemic level, bearing in mind that the effectiveness of agroecology strategies in addressing climate change is highly dependent on the local agroclimatic conditions[70]. Current evidence shows that fostering agroecology to build resilience can be recognized as a viable climate change adaptation strategy[71]. Within agroecology, the main practices that support climate change adaptation are those that provide shade (therefore cooling), and increase soil and plant moisture retention (to counteract water loss).

Agroecology is a compelling framework for adaptation – but at the same time, given the unpredictability and increasing frequency and severity of climactic events – including higher

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[67] Snapp S, Kebede Y, Wollenberg E, Dittmer KM, Brickman S, Egler C, Shelton S. 2021. Agroecology and climate change rapid evidence review: Performance of agroecological approaches in low- and middle- income countries. Wageningen, the Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

[68] Zenda, M., & Rudolph, M. (2024). A Systematic Review of Agroecology Strategies for Adapting to Climate Change Impacts on Smallholder Crop Farmers' Livelihoods in South Africa. *Climate*, *12*(3), 33. https://doi.org/10.3390/cli12030033

[69] Leippert, F., Darmaun, M., Bernoux, M. and Mpheshea, M. 2020. *The potential of agroecology to build climate-resilient livelihoods and food systems.* Rome. FAO and Biovision. https://doi.org/10.4060/cb0438en

[70] Zenda, M., & Rudolph, M. (2024). A Systematic Review of Agroecology Strategies for Adapting to Climate Change Impacts on Smallholder Crop Farmers' Livelihoods in South Africa. *Climate*, *12*(3), 33. https://doi.org/10.3390/cli12030033

[71] Leippert, F., Darmaun, M., Bernoux, M. and Mpheshea, M. 2020. *The potential of agroecology to build climate-resilient livelihoods and food systems.* Rome. FAO and Biovision. https://doi.org/10.4060/cb0438en

temperatures – it is important to understand and account for the constraints that can limit its reach[72]. All species of crops, animals and insects have thresholds, and when that threshold range is reached, they can migrate. Even here, there is still evidence of instances where agroecological practices can still adapt to these changes.

But – what happens when the threshold has reached its limit? For agricultural production, temperature overshoot cannot be overcome through agroecology alone because of heat threshold limits – so what other options are there? In addition to agricultural choices and practices, and increasing agroecosystem resilience through systemic approaches, innovation-based solutions can play a role by combining or applied together with an agroecosystem approach. Innovative technologies can include new breeding technologies and agrivoltaic and smart agricultural applications. The combination of natural capital and technologies could be defined as an "innovation-based solution" able to support and increase ecosystem service flow in agroecosystems[73].

CONCLUSIONS

This document has been prepared to address just one aspect of agroecology: can it be a strategy to address temperature overshoot from an agricultural production perspective. We also focused on the potential of agroecology to counter extreme heat by lowering temperatures. But adapting to higher temperatures is more than just regulating heat – it also works with ecological processes to adapt to the *impacts* of heat (e.g. increased incidences of pests and diseases). What this paper does not do is discuss the benefits of agroecology from a climate change mitigation perspective. Yes, agroecological practices help farmers adapt to extreme temperatures, but those same practices *also* have mitigation benefits, for example carbon sequestration (e.g. by increasing vegetative cover). Agroecology has both positive adaptation and mitigation outcomes, and this is a point in favour for considering agroecology as a viable strategy for farmers facing climate change.

So – what is it about agroecology that makes it a strong candidate for adaptation to temperature overshoot? Agroecology increases climate resilience, and it is this aspect which makes it a strong candidate for adaptation to temperature overshoot because of 1) its "all inclusive" agricultural approach, including practices that have been shown to adapt to warmer temperatures; 2) its ecologically-based character; 3) it works at the system level; and 4) its consideration of social equity and participation.

While the 2022 IPCC report Climate Change 2022: Impacts, Adaptation and Vulnerability[74] states, with a very high degree of confidence, that progress in adaptation planning and implementation has been observed across all sectors and regions, generating multiple benefits, it also found –

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[72] Altieri, M.A., Nicholls, C.I., Montalba, R., Vieli, L. & Vasquez, L.L. (2025). Agroecology and the limits to resilience: extending the adaptation capacity of agroecosystems to drought. Front. Agron. 7:1534370. doi: 10.3389/fagro.2025.1534370

[73] Semeraro, T., Scarano, A., Leggieri, A., Calisi, A., & De Caroli, M. (2023). Impact of Climate Change on Agroecosystems and Potential Adaptation Strategies. *Land*, *12*(6), 1117. https://doi.org/10.3390/land12061117

[74] IPCC, 2022: Summary for Policymakers [H.-O. Pörtner, D.C. Roberts, E.S. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem (eds.)]. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 3–33, doi:10.1017/9781009325844.001.

with a high degree of confidence - that adaptation progress is unevenly distributed and that there are adaptation gaps. The report also found (high confidence) that opportunities for *transformational* adaptation are reduced because of the immediate/near-term nature of most initiatives.

Can agroecology address *transformational adaptation?* Agroecological transformations encompass shifts from a fossil fuel dependent, unequal global agri-food system to be more biodiverse, resilient, democratized, plural and equitable. Efforts to support agroecological transformation can also empower peoples' capacities to take action, particularly those marginal, vulnerable, and disenfranchised. For scaling up agroecology though, there is a need for planning, policy support, and further research[75].

Also - adaptation opportunities for agricultural sub-sectors will have to be implemented under the umbrella of the impacts of systemic failures. In the future, multiple climatic and non-climatic risks and events will interact, and adaptation strategies need to be flexible to address this. The question is, can an agroecological approach be used to adapt to these systemic failures? The study on climate change adaptation in the Mediterranean region provides one answer, based on the systemic failures identified. The study says that in addition to higher than average warming and more frequent extreme climate events, other components of global change affecting the Mediterranean basin include biodiversity loss, freshwater overuse, disrupted nutrient cycles, soil degradation and altered fire regimes, in a context of high population density, water scarcity, high dependence on biomass and energy imports, and the prevalence of highly specialized, low diversity agroecosystems. The study goes on to say that a systemic approach can be provided by agroecology, and highlights that agroecology's "holistic framework" nature enables the recovery and assessment of traditional knowledge and the cocreation of new local knowledge for enhancing resilience[76].

In conclusion, some future questions are:
- With global temperatures rising above 1.5°C, can agroecology be a successful strategy at scale?
- Can agroecology be implemented under the umbrella of the impacts of systemic failures?
- Can agroecology positively influence systemic impacts?
- Can agroecology speak to all four pillars of food security?
- What does the political economy of beyond 1.5°C look like, and does it relate to agroecology?

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[75] Kerr, R. *et al.* (2023). Agroecology as a transformative approach to tackle climatic, food, and ecosystemic crises. *Current Opinion in Environmental Sustainability*, 62. https://doi.org/10.1016/j.cosust.2023.101275.

[76] Eduardo Aguilera, Cipriano Díaz-Gaona, Raquel García-Laureano, Carolina Reyes-Palomo, Gloria I. Guzmán, Livia Ortolani, Manuel Sánchez-Rodríguez, Vicente Rodríguez-Estévez. (2020).
Agroecology for adaptation to climate change and resource depletion in the Mediterranean region. A review. *Agricultural Systems,* 181. https://doi.org/10.1016/j.agsy.2020.102809.