

# Info Note

## What is the scientific basis for climate-smart agriculture?

*Preliminary findings from a quantitative synthesis of what works*

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### Key messages

- Quantitative syntheses generate an unbiased assessment on the potential of management practices to achieve CSA benefits.
- Synergies among productivity, resilience and mitigation occur the majority of the time with CSA; however, trade-offs are also apparent.
- A diverse range of factors limit adoption of CSA and need to be considered to match practices with places.

Climate-smart agriculture (CSA) is a systematic approach to agricultural development. It intends to address climate change and food security challenges simultaneously across levels, from field management to national policy, with goals to 1) improve **food security** and agricultural **productivity**, 2) increase the **resilience** of farming systems to climate change, and 3) **mitigate** greenhouse gas (GHG) emissions or sequester carbon. After the introduction of the CSA concept in 2010, development organizations, national governments, and donors have quickly adopted a “climate-smart” agenda.

### Why examine the climate-smartness of farm management practices?

Farm and field level management practices represent a key component of CSA. Farm level technologies represent a broad category of direct activities farmers can undertake on their fields, in livestock husbandry, or through management of communal lands. Actions might include anything from adopting drought resistant crop varieties, to reducing stocking rates of animals, to changing harvesting and postharvest storage techniques. The vast number of farm level options that might meet CSA objectives coupled with the large number of possible outcomes that can fit under the three pillars of CSA has led many development practitioners, scientists, and governments to the question ‘*what is CSA and what is not CSA*’?

This question, however, presents a false choice. By definition, CSA is context specific and subject to the priorities of farmers, communities, and governments where it is being implemented. Until now, little empirical evidence has been put forth to systematically evaluate what CSA practices work where. Instead, CSA is often supported with case studies, anecdotes, or aggregate data, which paint an incomplete picture of both the potential and challenges of CSA.



*Figure 1. Examples of climate-smart practices (white text) leading to food and nutrition security and poverty alleviation (yellow text) in the Uluguru Mountains, Tanzania. Photo: T. Rosenstock (ICRAF).*

The lack of comprehensive information on CSA is not surprising, given its infancy as a concept and the fact that it includes a wide diversity of food system/rural livelihood solutions. In response, we have been conducting a quantitative review to evaluate the evidence on the effectiveness of management practices to achieve productivity, resilience, and mitigation objectives.

## A quantitative approach

Our team—composed of scientists from the World Agroforestry Centre (ICRAF), CGIAR Research Program on Climate Change, Agriculture, and Food Security (CCAFS), Food and Agriculture Organization of the United Nations (FAO), and the International Center for Tropical Agriculture (CIAT)—has been unpacking the CSA concept in a way that enables us to bring data to the CSA discussion. We have been conducting a quantitative meta-analysis, which is a statistical method that combines results across research studies in a rigorous way. Meta-analyses produce (1) maps of the evidence base (e.g., locations and topics of what has been studied) and (2) estimates of effect size (as well as its statistical reliability/confidence intervals), in this case the expected change in an outcome when applying potential CSA versus conventional management practices. The impetus for this effort came from conversations among scientists, development specialists and development partners about the need for objective, robust and unbiased evidence to help move CSA from the meeting room into the field.

The team assessed 150,367 studies for relevance to our key questions: *what is the evidence base for oft-cited “climate-smart” farm-level management practices and what are the barriers to adoption of these practices?* Relevant papers had data on the impact of one of 73 agronomic, agroforestry, livestock, energy, or postharvest management practices on more than 55 outcomes in productivity, resilience/adaptive capacity, or mitigation such as yields, gender differentiated labor use, or soil organic carbon, respectively. Data on social or biophysical constraints to adoption are also captured in a complementary meta-database that uses the same practice codes (see Rosenstock et al. 2015 for full description of methods). Studies were located by searching the Web of Science and SCOPUS databases by search terms indicative of practices and outcomes. Articles had to have primary data on both a CSA and conventional practice, to include data on at least one outcome relevant to productivity, resilience, or mitigation, and to be conducted in a developing country. The final library includes 7,497 studies. This makes the ‘**CSA Compendium**’ the largest meta-analysis of agricultural systems in terms of the number of studies included by more than an order of magnitude.

Data are compiled into a database manually from each study. So far, our team has extracted data from articles that have been conducted in Africa (~1,350) or contain data relevant to climate change mitigation (~400). Data retrieved from studies include information on location, climate, soils, crop and livestock species, outcome values for both conventional and treatment practices and coefficients of empirical model results (when applicable).

The team and individuals make decisions about search terms, article screening, and data extraction, which can potentially introduce error into the analysis. However, mechanisms to identify bias and maintain consistency, such as having article reviewers meet consistency standard in applying the inclusion/exclusion criteria (Cohen’s Kappa > 0.6), have been used throughout the search, review, and data extraction process.

## Synergies and trade-offs

The fundamental premise underlying CSA is that food security<sup>1</sup> and climate change can be addressed simultaneously with synergistic effects. A synergy means that when one outcome improves another does as well. The opposite of synergies are trade-offs. Trade-offs represent compromise between outcomes: when there is improvement in one, another declines. Whether CSA practices generate synergies or trade-offs is a testable hypothesis with our meta-analysis.

With our database, we can compute the average effect that changing from conventional management practices to a potential CSA practice has on productivity and resilience among studies that measured indicators of both outcomes (see Rosenstock et al. 2015 for description of statistical approach). We intentionally only select studies that measured both outcomes, because the impact of management practices depends on location and thus it is spurious to compare results of studies between locations in different biophysical or social contexts.

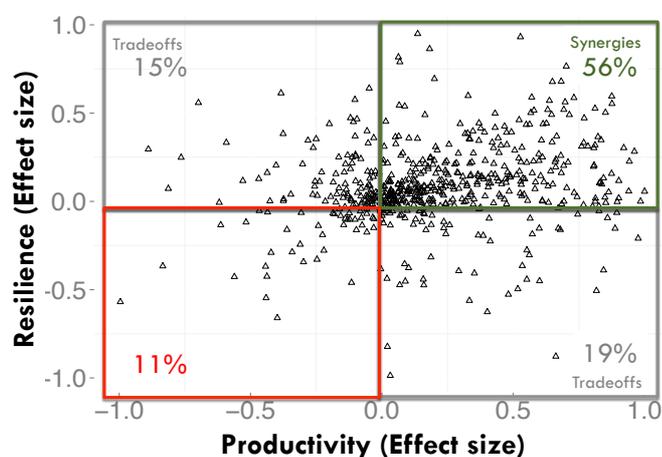


Figure 2. Synergies and trade-offs with CSA. X and y-axes are on log-scale. A value of 0.5 is approximately equal to a 60% change between CSA and conventional management. A value of 1.0 is approximately equal to 271% change.

Using a sub-sample of 754 studies, we found that indeed, adoption of CSA produces synergistic effects 56% of the time (Figure 2). However, 31% of the pairwise compari-

<sup>1</sup> Our analysis only addresses two of the four dimensions of food security (availability and stability).

sons suggest that there are potential for trade-offs, e.g. a practice might improve production but decrease resilience or vice versa. These data show, at an aggregate level, that CSA can indeed produce intended synergies. However, variation in effects is large suggesting that caution should be taken when considering specific CSA practices or specific trade-offs.

Regarding the analysis of mitigation potentials our data can also guide the decisions of policy makers, development practitioners, and scientists interested in understanding whether there are co-benefits between soil carbon sequestration and productivity. An affirmative answer to this question would suggest that small farmers could improve livelihoods and help stabilize the global climate. In our database, we found 34 long-term studies on CSA that measure change in soil carbon and productivity (Figure 3, Richards et al. *in prep*; Soussana et al. *in review*).

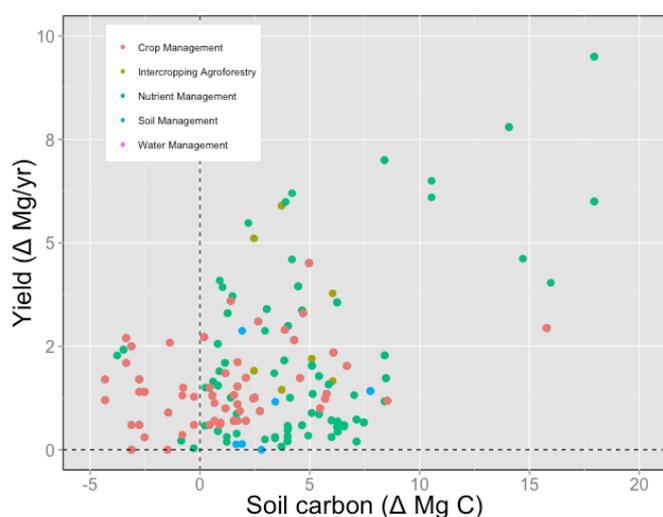


Figure 3. Co-benefits found between changes in yield and changes in soil carbon sequestration in 34 field experiment lasting longer than 4 years in developing countries.

These studies clearly show that increasing soil carbon can increase crop yields, though the relative impact depends somewhat on the type of management implemented (Figure 3). In few cases will yields decline and only with select management techniques (e.g., some crop rotations) did soil carbon decrease. These data suggest that CSA can contribute to food security and climate stabilization.

The two examples presented here illustrate the power of data to answer key questions about CSA. Further analyses disaggregated by places and practices are possible, and are being explored in participatory ways with policy makers and farmers to support scaling up of CSA in 2016.

## Barriers to adoption

Understanding the potential impacts of various practices on CSA outcomes tells only part of the story if CSA is going to be translated into meaningful impact on the ground.

Equally important is to understand what are the major constraints to adoption or sustained use of improved CSA management practices.

Our team compiled the available literature on the barriers constraining use of farm management practices captured in the compendium. Socioeconomic studies typically use probit or other econometric models to examine the statistical significance of household and socioeconomic variables on the adoption of new practices. With meta-analysis, it is possible to combine the research results to gain a general understanding of the direction and magnitude of the effect. That is, does the variable enable or obstruct adoption significantly and by how much. Our synthesis of adoption of CSA is still on-going and results will be released in early 2016.

We can, however, already begin to map the significance of the various factors on adoption. Table 1 shows an analysis of 80 studies that conducted household surveys to examine the determinants of adoption of practices that are often cited as potential CSA.

When looking at the results of these studies, a few key messages emerge immediately. To begin with, the majority of the factors are not statistically significantly correlated with adoption. For every factor, at least 70% of the studies show non-significant results, suggesting no consistent impact of the factor on adoption. Oftentimes, non-significance in statistical tests is due to large variation in the underlying data, highlighting the context specificity of the factors constraining adoption.

Some factors, however, such as access to information, extension and credit have positive influences on adoption across a considerable number of the studies that included this factor. This would suggest that CSA programs need to focus on information delivery to support changes in practices as well as financing to overcome initial investment barriers, providing actionable priorities to inform program and policy development.

Table 1. Constraints to adoption of agronomic and agroforestry CSA practices. Ns = not statistically significant, - and + = negatively and positively correlated with adoption, respectively.

Factor	Ns	-	+	% ns
Access to credit	39	1	11	76
Information and extension	60	3	20	72
Asset base	32	1	3	89
Social networks	52	1	7	87
Off-farm income	42	11	6	71
Gender	58	3	15	76
Market access	53	5	5	84

## CSA requires a new research paradigm

We have compiled the most comprehensive database on the impacts of farm management practices and constraints to adoption to date. When mapping the location and objective of the studies, it becomes clear that though studies have been conducted throughout the developing world, large gaps in both geographies and topics persist. As one might expect, fertilizer use on maize to improve yields is thoroughly covered, while data on other key components such as the impact on male/female labor are less researched. Notably, only about 40% of the studies contain data on two outcomes of CSA (e.g., adaptation and mitigation) in the same study. Even more striking, only about 2% of the studies contain data on all three components. The lack of co-located research on all three components suggests a need for a new research paradigm to support CSA; an approach that can look at the synergies and trade-offs of farm management practices under specific social and biophysical contexts, in order to inform decision makers and development practitioners.

## Conclusion

Our quantitative synthesis of CSA provides the most thorough view of the scientific basis for CSA to date. When complete, it will show where and what has been researched and provide an objective analysis of the literature. These can provide a much needed input into rapidly emerging CSA investments. Though more comprehensive than any other previous effort, the CSA Compendium can still be improved and we look forward to working with partners to widen the scope of practices, include grey and non-english language literatures, link with downscaled climate change projections and integrate CSA services (e.g., climate-information).

## Further Reading

- Rosenstock et al. 2016. The scientific basis of climate-smart agriculture: A systematic review protocol. CCAFS Working Paper No. 138. 37 pg.
- Lipper et al. 2014. Climate-smart agriculture for food security. *Nature Climate Change*, 4:1068-1072.
- Neufeldt et al. 2013. Beyond climate-smart

agriculture: Toward safe operating spaces for global food systems. *Agriculture & Food Security*, 2:12-18.

- FAO. 2014. Climate-smart agriculture sourcebook. FAO, Rome. 570 pg.

Research led by:



*This series of briefs reports on the lessons learned and opportunities derived from the GGIAR Research Program on Climate Change, Agriculture, and Food Security's Flagship Project 'Partnerships for Scaling Climate-Smart Agriculture' (P4S). P4S is co-led by the World Agroforestry Center (ICRAF) and the International Center for Tropical Agriculture (CIAT). P4S engages stakeholders globally to support scaling up of CSA through four interrelated activities: (1) situation analysis, (2) targeting and prioritizing, (3) program support, and (4) monitoring, evaluation and learning. The CSA Compendium, part of P4S' workpackages 2-4, is a key output aimed to deliver unbiased information on the evidence base for CSA, specifically identifying what is well known versus what is more uncertain. All data will be publically available for search and analysis in 2016.*

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## CCAFS and Info Notes

The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) is a strategic partnership of CGIAR and Future Earth, led by the International Center for Tropical Agriculture (CIAT). CCAFS brings together the world's best researchers in agricultural science, development research, climate science and Earth System science, to identify and address the most important interactions, synergies and tradeoffs between climate change, agriculture and food security.

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