



RESEARCH  
PROGRAM ON  
Grain Legumes and  
Dryland Cereals



## Identifying Low Emissions Development Pathways – Synergies and Trade-offs: A Case Study of Mahbubnagar District, Telangana, India

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### 1. Abstract

This case study examines the opportunities for obtaining synergies between agricultural productivity, whole-farm profitability and greenhouse gas (GHG) mitigation and highlights where trade-offs exist. We explore how agricultural practices and systems can be designed and managed to balance the synergies and trade-offs for small-holder farmers in semi-arid India. We used data on farm-household characteristics and agricultural practices from 100 farm-households of Telangana state, India. Quantifying synergies and trade-offs between profitability, adaptation and mitigation we employed simulation modelling- crop, livestock and whole-farm simulation models, and Cool Farm Tool to estimate net GHG emissions. Our analysis reveals that specific plot-level crop management strategies and farm-level enterprise interventions can increase profitability as well as benefit climate change mitigation. It depicts how farming systems can be managed to achieve synergies between profitability and mitigation outcomes and where, if any trade-offs exist. Combinations of reduced tillage, retaining crop-residue, improved nitrogen management, utilizing organic manure, improved livestock feeding practices, introducing agro-forestry could contribute to GHG abatement and improved profitability at our study site. Such multi-model systems analysis using participatory design and tools could help practitioners and policymakers to identify and promote use of management practices that can help achieve multiple objectives and guide investments towards synergistic climate smart agriculture strategies. Our study contributes empirical evidence to the debate surrounding integrated approaches to sustainable development goals and adaptation and mitigation objectives.

### 2. Context and challenge, including key interactions (range and nature) the case study addresses

Agricultural production will need to increase by at least 60% by 2050 to meet the demand of the world's growing population (FAO 2015). Simultaneously it must provide economic opportunities for hundreds of millions of rural poor who depend on agriculture for their livelihoods and reduce negative environmental impacts. A rough estimate puts global greenhouse gas emissions from agriculture, both crop production and livestock at 6.5 giga tons of carbon dioxide equivalent (Gt. CO<sub>2e</sub>), accounting for 13 percent of net worldwide greenhouse gas emissions in 2010 (Smith et.al. 2014). Agriculture lies at the crossroads of food-security, climate-change

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adaptation and mitigation efforts. The need to maintain food security in the face of changing climate has pushed governments and development actors to focus efforts on improving adaptation, rather than mitigation till date. However, going forward both adaptation efforts to maintain crop yields and livelihoods, and mitigation efforts to reduce GHG emissions are of global significance. While Climate Smart Agriculture (CSA) framework systematically aims to integrate productivity, adaptation and mitigation into planning and implementation of sustainable agricultural systems (Lipper, 2014), information on contribution of various interventions to these three is missing. The growing need to pursue production, adaptation and mitigation goals in agricultural systems, calls for triple-win solutions with positive contributions to productivity, adaptation and mitigation. With a contribution of more than a third to global agricultural emissions, smallholder farming in developing countries has a major role to play in achieving these targets. The implication, therefore is that approaches to mitigation measures need to be introduced in the context of agricultural development. An emerging paradigm for promoting mitigation in agriculture is the Low-Emissions Development (LED). LED in agriculture can be defined as increasing agro-ecological productivity and sustainability in ways that also reduce agricultural GHG emissions (Wollenberg. L 2017). LED strategies in agriculture acknowledge broader sustainable development goals and identify mitigation practices compatible with these goals. LED strategies therefore foster food security and economic growth while simultaneously reducing GHG emissions. With a focus on minimizing the ‘emissions intensity’ – the GHG emissions per unit of yield, LED ideally contributes to the three pillars of climate smart agriculture: Productivity, Adaptation and Mitigation.

Data collected from 100 smallholder farms of Wademan Village, Bijinapalli mandal, Mahabubnagar district located in Telangana state, India were used in this study. The representative farm households are interviewed based on a structured questionnaire pertaining to general farm structure, current management practices, cropping systems, crop yields, livestock and general socio-economic conditions.

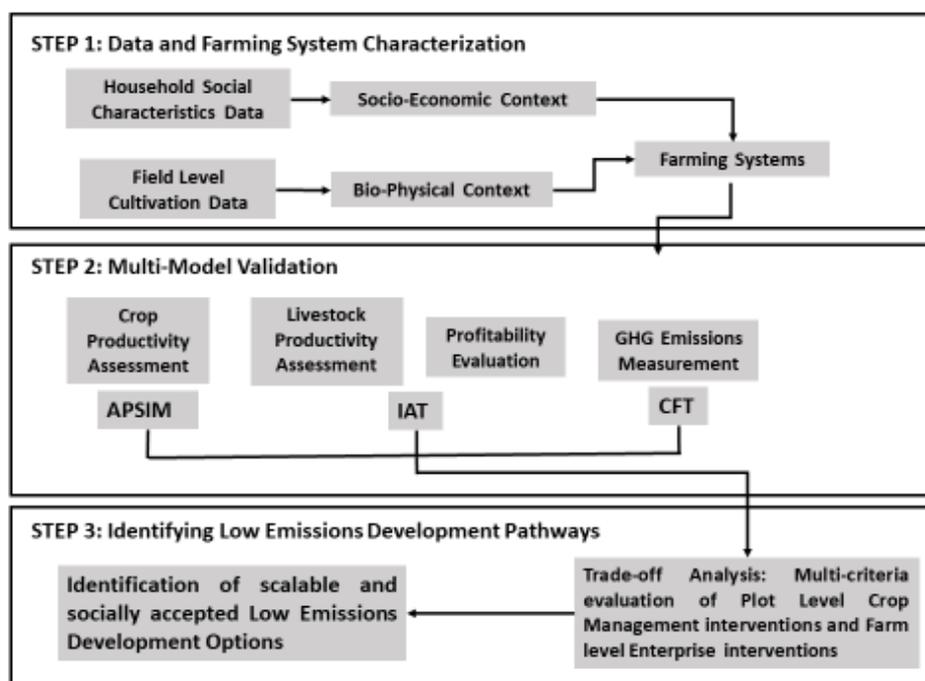
**Table 1.** Basic agro-ecological characteristics of the study sites

Particulars	
Latitude	16.5500°N
Longitude	78.2000°E
Average annual rainfall (mm)	749mm
Agro-climatic Region	Southern Plateau and Hills region; Semi-Arid
Taxonomic Soil Classification	Majorly Inceptisols followed by Entisols, Alfisols and Vertisols, respectively.
Major Crops	<b>Kharif Rainfed:</b> Red gram, Groundnut, Cotton, Castor, Sorghum <b>Kharif Irrigated:</b> Rice, Groundnut <b>Rabi Rainfed:</b> Sorghum, Bengal gram, Sunflower <b>Rabi Irrigated:</b> Paddy, Vegetables, Groundnut

*Note: Kharif is the rainy season; Rabi is post-rainy season*

Quantifying synergies and trade-offs between profitability, adaptation and mitigation at the farmer-field level is a daunting task, one which entails huge costs both in terms of time and investments. This assessment, therefore employed simulation modelling as a tool to find the potential synergies and trade-offs between economic profitability and mitigation opportunities in small-holder farming systems. Data pertaining to the land management practices, livestock feeding practices, input costs and market prices for various agricultural produce were collated from the farm household surveys and used as inputs into crop, livestock and whole-farm simulation models used in this study. The quantification approach is explained in the following figure:

**Figure 1.** Methodological framework



### 3. How did research efforts deal with the synergies and trade-offs? [b] in the development of partnerships/delivery approaches]

#### a) in the development of the TOC and impact pathways

We examined the opportunities for obtaining synergies between agricultural productivity, whole-farm profitability and GHG mitigation and highlighted where the trade-offs exist for small-holder farmers. We also explored how agricultural practices and systems can be designed and managed to balance the synergies and trade-offs. Research to date on this subject was focused on developing conceptual frameworks and approaches to evaluate synergies between production, adaptation and mitigation activities at both farm and landscape level (Harvey et.al. 2013, Locatelli et.al 2015, and Gregoria et.al. 2017). This work builds on that research and attempts to quantify the synergies and trade-offs from a small-holder farmers' perspective. This would help practitioners and policymakers to identify and promote use of management practices that can help achieve multiple objectives and guide investments on climate smart agriculture.

Following the quantification approach as explained above; we first divide the farmers into three farm clusters based on their socio-economic characteristics and biophysical contexts. Following management practices were evaluated using APSIM (Agricultural Production Systems Simulator; Keating et al., 2003), IAT (Integrated Assessment Tool; McDonald et.al, 2004) and CFT (Cool Farm Tool) to derive the best possible strategies that provide highest synergies and least trade-offs between mitigation and profitability:

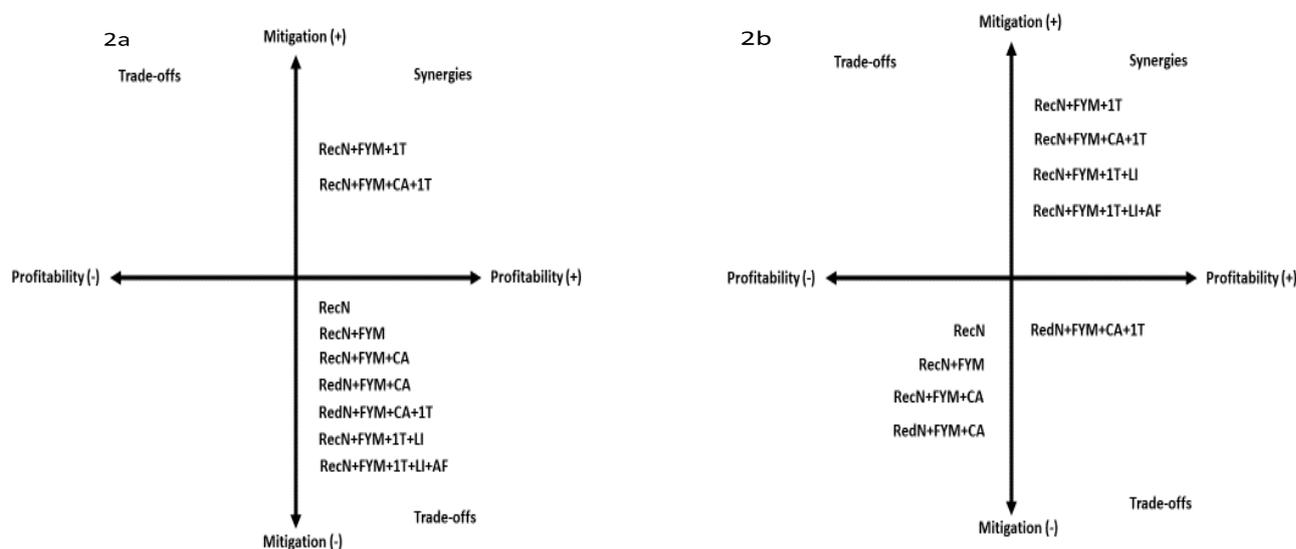
- (i) Plot-Level Crop Management Interventions:
  1. Integrated Nitrogen Management – Recommended N, Reduced N
  2. Manure Application (FYM)
  3. Residue Management (CA)

4. Reduced Tillage (T)

(ii) Farm-Level Enterprise Interventions:

1. Improved Livestock Fodder Management (LI)
2. Agroforestry (AF)

Below figures depict how farming systems can be managed to achieve synergies between profitability and mitigation outcomes and where, if any trade-offs exist (Harvey et.al 2013).

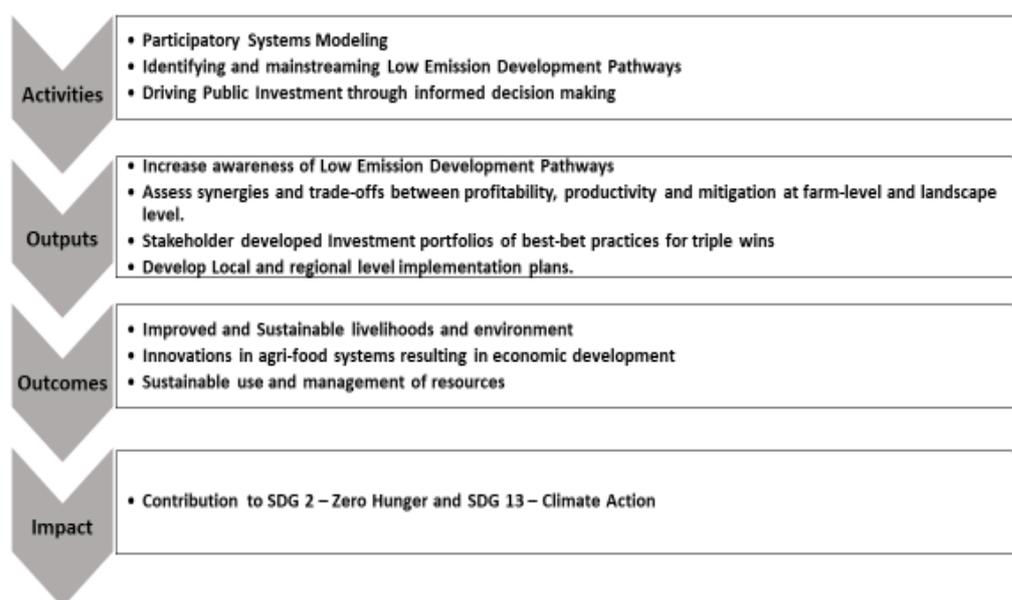


**Fig 2a, 2b.** Profitability and Mitigation Synergies and Trade-offs under various management interventions for Farm Cluster-1 and 2

Specific plot-level crop management strategies and farm-level enterprise interventions can increase profitability as well as benefit climate change mitigation. Combinations of reduced tillage, retaining crop residue, improved nitrogen management, utilizing organic manure, improved livestock feeding practices and introduction of agroforestry could contribute to GHG abatement and improved profitability at our study site. However, to realize the synergies presented in this study, several adoption barriers might exist, such as lack of affordability and access to technology, lack of information, risk preferences, poor access to input and output markets, and lack of access to credit (Barrett et al. 2002; Lee 2005; Herrero et al. 2010; Bryan et.al . 2013). Such barriers could prevent the adoption and upscaling of management practices evaluated in our scenarios. For example, improved livestock feeding practices is likely to be an opportunistic venture for farmers, but access to fodder and associated price fluctuations can be a key factor in farmer decision-making. Reduced tillage operations shows promising results an important practice for reducing green-house gas emissions and also reducing costs and increasing net economic returns overall. However, lack of cost effective access to appropriate machinery (ex: zero till drill) could impede successful adoption of this practice, especially among small and medium scale farmers. Crop residue burning may be an important tool for timely-sowing of the crop and also for managing weeds from a farmers' perspective.

**The theory of change** can be described as follows: Given multiple objectives and multiple options, such decision-support frameworks can help determine investment priorities. This multi-model systems modeling prioritization framework can guide decision makers through a process of narrowing down long lists of applicable Climate Smart Agriculture (CSA) practices that can contribute to all the three pillars of CSA to guide investment

portfolios. It may result in a paradigm shift in the thinking of practitioners and policy makers in developing countries not to excessively rely on only adaptation options but to leverage triple-win solutions for enhanced productivity, profitability and mitigation. The framework integrates analytical tools into a process that ensures triple-win strategies are at the core of investment choices. A simplified series of impact pathway can be illustrated as follows:



**b) in the development of partnerships/delivery approaches**

Going further this approach is being field-tested in mixed crop-livestock systems of 10 districts from Telangana, Andhra Pradesh and Maharashtra states in Semi-Arid India, with plans to expand to other sites and agro-ecosystems as a progression. Initial pilot projects are implemented collaboratively with the 10 Krishi Vigyan Kendra (KVKs) - the Farm Science Centers which are the major extension agents in the Indian agricultural system. These pilots provide a validation of the approach and methods, generating field level information, highlighting technical gaps and promising directions.

**c) in the development of metrics**

Our process for the development of metrics involved: (i) Capacity building of national researchers as well as extension agents (KVKs) on trade-off analysis through multi-model systems approach; (ii) Identifying the triple-win options relevant for a particular farm type (context specific); (iii) Analyzing the key constraints and challenges in implementation and providing initial technical back-stopping and handhold support to the extension systems (KVKs).

**4. What kinds of partnerships were critical?**

The key partners are the mid-level policy actors, NARS scientists and the KVKs (extension agents). The policy makers influence and guide the public and private investment decisions; the researchers trained on modelling framework provide technical backstopping to extension system and KVKs work with farmers to promote such decision support tools.

## 5. Lessons learnt, including knowledge gaps and good practices in employing these approaches at scale

Our study and multi-model framework very distinctly identify triple-win options and hence contributes to investment prioritization for scaling CSA under smallholder farm systems. However more efforts are needed to build capacity of NARES on such approaches.

Access to better data is a challenge to calibrate the work of research, policy and development communities towards identifying and implementing low emission development pathways in smallholder farming systems.

Despite the above recognized challenges to integrating profitability and mitigation efforts, with a combination of targeted scientific evidence, policy and institutional reform, these barriers could be overcome, and genuine win-win solutions that boost food production, protect ecosystems and increase economic opportunities for the poor can be realized.

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### References

- Smith P, Bustamante M, Ahammad H et al. (2014) Agriculture, forestry and other land use (AFOLU). In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (editors: Edenhofer O, Pichs-Madruga R, Sokona Y et al.). *Cambridge University Press*, pp. 811–922.
- Lipper, L., Thornton, P., Campbell, B.M., Baedeker, T., Braimoh, A., Bwalya, M., Caron, P., Cattaneo, A., Garrity, D., Henry, K. and Hottle, R., 2014. Climate-smart agriculture for food security. *Nature Climate Change*, 4(12), p.1068.
- Harvey, C.A., Chacón, M., Donatti, C.I., Garen, E., Hannah, L., Andrade, A., Bede, L., Brown, D., Calle, A., Chara, J. and Clement, C., 2014. Climate-smart landscapes: opportunities and challenges for integrating adaptation and mitigation in tropical agriculture. *Conservation Letters*, 7(2), pp.77-90.
- Locatelli, B., Pavageau, C., Pramova, E. and Di Gregorio, M., 2015. Integrating climate change mitigation and adaptation in agriculture and forestry: opportunities and trade-offs. *Wiley Interdisciplinary Reviews: Climate Change*, 6(6), pp.585-598.
- Wollenberg, L., 2017. The mitigation pillar of Climate-Smart Agriculture (CSA): targets and options. *Agriculture for Development*, (30), pp.19-22.
- Di Gregorio, M., Nurrochmat, D.R., Paavola, J., Sari, I.M., Fatorelli, L., Pramova, E., Locatelli, B., Brockhaus, M. and Kusumadewi, S.D., 2017. Climate policy integration in the land use sector: Mitigation, adaptation and sustainable development linkages. *Environmental Science & Policy*, 67, pp.35-43.
- Keating, B.A., Carberry, P.S., Hammer, G.L., Probert, M.E., Robertson, M.J., Holzworth, D., Huth, N.I., Hargreaves, J.N., Meinke, H., Hochman, Z. and McLean, G., 2003. An overview of APSIM, a model designed for farming systems simulation. *European journal of agronomy*, 18(3-4), pp.267-288.

McDonald, C.K., MacLeod, N., Lisson, S., Ash, A., Pengelly, B., Brennan, L., Corfield, J., Wirajaswadi, L., Panjaitan, T., Saenong, S., Sutaryono, Y., Padjung, R., Rahman, R., Bahar, S., 2004. Improving Bali cattle production in mixed crop–livestock systems in eastern Indonesia using an integrated modelling approach. In: Wong, H.K., et al. (Eds.), *New Dimensions and Challenges for Sustainable A.M. Komarek et al. / Agricultural Systems* 109 (2012) 16–24 23 *Livestock Farming, Proceedings of the 11th Animal Science Congress*, Kuala Lumpur, 2004, vol. II, pp. 116–119

Barrett, C.B., Place, F., Aboud, A. and Brown, D.R., 2002. The challenge of stimulating adoption of improved natural resource management practices in African agriculture. *Natural resource management in African agriculture*, pp.1-21.

Herrero, M., Thornton, P.K., Notenbaert, A.M., Wood, S., Msangi, S., Freeman, H.A., Bossio, D., Dixon, J., Peters, M., van de Steeg, J. and Lynam, J., 2010. Smart investments in sustainable food production: revisiting mixed crop-livestock systems. *Science*, 327(5967), pp.822-825.

Lee, D.R., 2005. Agricultural sustainability and technology adoption: Issues and policies for developing countries. *American Journal of Agricultural Economics*, 87(5), pp.1325-1334.

Bryan, E., Ringler, C., Okoba, B., Koo, J., Herrero, M. and Silvestri, S., 2013. Can agriculture support climate change adaptation, greenhouse gas mitigation and rural livelihoods? Insights from Kenya. *Climatic Change*, 118(2), pp.151-165.

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