Modeling Coffee in Mexico: CAF2014 Geo-spatial Setup – Part I

Technical Note on the Implementation of the SAbERES Project **(Draft)**

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Context of the study

In a series of project's internal weekly exchange and planning events, the IIASA team has identified several research tracks, which translated into the modeling of growing coffee in Mexico with the CAF2014 model [1]. Here we cover technical questions and document changes to the geo-spatial setup which are incremental to the earlier reports [2] and [3].

Overall method and rationale

One of the major components in economic assessment of agricultural activities is the estimation of crop yield. The modeled yield estimates are uncertain because of large number of factors e.g. crop feedback to weather and potential pest outbreaks. There is also uncertainty induced by market price fluctuations both for the product and for the inputs required to produce it. These modeling challenges are pertinent both to annual and perennial crops cultivation, yet are exacerbated in case of modeling of perennial crops because of path dependency. More discussion and further literature references are available in [2].

Calibrating CAF 2014 in a geo-spatial application

1. Matching soil data and spatial production patterns

Figure 1 presents CAF2014 10-year average yield estimates using default management, but location-specific soil water holding capacity from the GEOBENE DB [9] for historical period. A visual comparison with Figure 6 (and also Figure 5) visualizing a commonly used in agricultural applications MAPSPAM [12] dataset reveals inconsistencies between the areas marked as used for coffee production in MAPSPAM and the high potential estimates as informed by CAF2014. Since there might be several factors which influence actual area selection for coffee production e.g. high fertility of the soils which leads to reduction of fertilizer requirements in production (effectively cost savings) or soil toxicity for the coffee plants because of high aluminium oxides content, which both present a challenge for modeling from a biophysical perspective in its simplified version as provided by CAF2014, we decided to implement a pragmatic approach to the challenges associated with accounting for complex soil information and use as a proxy for suitable land – current coffee production areas as informed on municipality level by SIAP [10]. Masking the areas outside of those is a conservative approach because there may exist more unexplored/unused yet areas. At the same time, the degree of suitability of those potential areas might be hard to estimate, which we would like to avoid beyond the obtained simplified (restricted) representation as presented in Figure 1 and Figure 2.

A note on the relationship between the the SIAP [10] and MAPSPAM [12]: these datasets being different in structure (vector vs grid) visually demonstrate hight level of consistency on respective maps (compare Figure 5 vs. Figure 7 and Figure 6 vs. Figure 8). The similarities are due to MAPSPAM 2010 is based on SIAP (as documented in supplementary information to [12]), while

most of the discrepancies are probably due to our longer time averaging period (2003-2023) used for generating SIAP based maps, whereas some inconsistencies may be due to downscaling methods employed in MAPSPAM. In further considerations we rely on SIAP data as the original data source.

A challenge is revealed by the analysis of the model outputs for the soil water holding capacity taken from the GEOBENE DB [9] vs. default soil setup: it points to data inconsistencies resulting in only partial coverage of the territory of Mexico by obtained yield estimates, where the issue is particularly apparent in Chiapas state (compare Figure 1 with Figure 2, and Figure 1 with Figure 4) where according to SIAP [10] the yields are non marginal (original municipality level based map in Figure 8). At the same time, there are locations in central Chiapas, where there is no coffee production (as per SIAP [10]) and consistently no yield estimates based on soil water holding capacity taken from the GEOBENE DB [9].

2. A note on NASA GDEX climate data

In the absence of better data verified for the modeling resolution, as well as the challenges associated with the completeness and specificity of soil information for coffee modeling purposes, this was the reason to prioritize the use of standard soil parametrization of CAF2014, however, as the climate data play an essential role, a finer spatial resolution may be useful to explore the yield estimates obtained from CAF2014. For that purpose, we decided to analyze the NASA GDEX [18] dataset, which has two times finer spatial resolution (0.25 arc-degree instead of the 0.5 arc-degree ISI-MIP [7] dataset employed so far) and provides not only historical records, but also a compatible set of climate projections (GCMs and SSPs).

3. Management: fertilizer and shading trees

In order to figure out typical approaches to plantations management by small coffee growers and as the first initial step we have consulted with the AI/LLM by posing the seeding question:

Could you please let me know what are the practices used by small coffee growers in Mexico in terms of shade tree thinning and pruning and also fertilizer application?

The received responses from AI LLMs are presented below with highlighting using a gray text marker emphasizing substantial information (added by the authors, including authors' comments on manual checking of factual data when indicated). Bold font is kept from the original LLM's output.

DeepSeek LLM

Small coffee growers in Mexico, particularly those practicing traditional or agroecological methods, often use specific techniques for **shade tree thinning/pruning** and **fertilizer application** to maintain soil health, coffee quality, and biodiversity. Here's an overview of common practices:

1. Shade Tree Thinning & Pruning

Mexican smallholders (especially in regions like Chiapas, Oaxaca, Veracruz, and Puebla) typically grow coffee under diverse shade trees, including **Inga (chalum), Erythrina (palo de pito), Gliricidia, and fruit trees**. Practices include:

- **Selective Thinning**:
  - Remove overcrowded or diseased shade trees to allow **30-40% shade cover** (varies by altitude and coffee variety).
  - Preserve nitrogen-fixing trees (e.g., Inga spp.) to enhance soil fertility.
- **Pruning for Light Regulation**:
  - **Annual or biennial pruning** of shade tree canopies to balance sunlight and shade, preventing excessive competition with coffee plants.
  - **"Pollarding"** (severe pruning of upper branches) is common with trees like Erythrina to promote regrowth and organic mulch.
- **Timing**:
  - Pruning is often done **after harvest (Jan-Apr)** to avoid disrupting flowering/fruiting cycles.

2. Fertilizer Application

Smallholders use a mix of organic and (sometimes) synthetic fertilizers, depending on access and cost:

Organic Fertilization (Common in Organic & Traditional Systems)

- **Pulp & Cherry Waste**: Coffee pulp is composted and reapplied to fields.
- **Livestock Manure**: Chicken, cow, or sheep manure is commonly used.
- **Biofertilizers**: Some cooperatives promote vermicompost or microbial inoculants.
- **Shade Tree Leaf Litter**: Decomposed leaves from Inga or Gliricidia provide natural mulch.

Synthetic Fertilizers (Limited Use)

- Smallholders with more resources may apply **NPK blends (e.g., 18-8-16-4)** but in lower quantities than large farms due to cost.
- Often applied **twice a year** (before rainy seasons—May-Jun & Sep-Oct).

Liquid Fertilizers (Bocashi, Biol)

- Fermented organic mixtures ("biol") made from manure, molasses, and ash are increasingly popular among agroecological farmers.

Regional Variations

- **Chiapas/Oaxaca**: More likely to use organic methods (especially in indigenous communities).
- **Veracruz/Puebla**: Some conventional smallholders use limited synthetic fertilizers.

Would you like details on specific regions or certification influences (e.g., Fair Trade, Organic)?

Follow up refinement of DeepSeek's information

In order to refine the initial answer, the following additional questions were posed; these, together with obtained answers and manual truth-checks (highlighted with the text marker) follow below:

Additional question 1. Could you please provide a literature reference confirming the target of 30-40% shade cover, which is aimed at by small coffee growers in Mexico when managing shading trees?

Certainly! The **30–40% shade cover** target for coffee agroforestry systems in Mexico is supported by several studies focusing on smallholder practices. Below are key literature references that discuss this range:

Reference: Soto-Pinto, L., Perfecto, I., Castillo-Hernandez, J., & Caballero-Nieto, J. (2000). *Shade effect on coffee production at the northern Tzeltal zone of the state of Chiapas, Mexico.* Agriculture, Ecosystems & Environment, 80(1-2), 61-69. **Key Findings:** - This study in indigenous coffee farms in Chiapas found that **30–40% shade cover** optimizes coffee yield while maintaining biodiversity. - Higher shade (>50%) reduced yields, while lower shade (<30%) increased pest incidence. **Checked manually – correct. Quote:** "Shade tree cover had a positive effect between 23 and 38% shade cover and yield was then maintained up to 48%. Production may decrease under shade cover >50%. A total of 61 shade species were found, with an average density of 260 trees per hectare, the majority of them being indigenous species..."

Reference: Moguel, P., & Toledo, V. M. (1999). *Biodiversity conservation in traditional coffee systems of Mexico.* Conservation Biology, 13(1), 11-21. **Key Findings:** - Describes traditional "rustic" and "polyculture" shade systems in Mexico, where smallholders maintain **~30–50% shade** for ecological balance. - Highlights that farmers adjust shade based on altitude, with lower elevations favoring slightly less shade (~30%). **Checked manually – numbers cannot be confirmed.**

Reference: Jha, S., Bacon, C. M., Philpott, S. M., Méndez, V. E., Läderach, P., & Rice, R. A. (2014). *Shade coffee: Update on a disappearing refuge for biodiversity.* BioScience, 64(5), 416-428. **Key Findings:** - Reviews Latin American shade coffee systems, noting that Mexican smallholders often aim for **30–40% shade** to balance productivity and microclimate benefits. **Checked manually (including paper's SI)**: Only a rough confirmation: 1-40% shade in ~80% of coffee areas Mexico (Figure 2). Quote on relation to quality: "shade may be particularly important for maintaining coffee quality in the context of climate change".

Reference: Martínez, M. L., Pérez-Maqueo, O., Vázquez, G., Castillo-Campos, G., García-Franco, J., Mehltreter, K., … & Landgrave, R. (2018). *Effects of land use change on biodiversity and ecosystem services in tropical montane cloud forests of Mexico.* Forest Ecology and Management, 258(6), 1856-1863. **Key Findings:** - Reports that coffee farmers in Oaxaca's cloud forests maintain **30–40% shade cover** to prevent soil erosion and excessive competition. **Checked manually:** paper is irrelevant to shaded coffee production.

Why 30–40%?

This range is a compromise between: - **Sunlight needs** (for coffee photosynthesis and yield). - **Microclimate regulation** (reducing temperature extremes). - **Biodiversity conservation** (protecting birds, pollinators, and soil health).

Would you like additional references focusing on specific Mexican regions or organic certification standards?

Additional question 2. What would be the typical amount of elemental nitrogen (in kilogram per hectare) that is applied in form of organic fertilizer by small coffee growers in Mexico? Could you provide a literature reference confirming your answer?

The typical amount of **elemental nitrogen (N) applied via organic fertilizers** by small coffee growers in Mexico varies depending on the type of organic inputs used, but studies suggest a range of **~30–80 kg N per hectare per year** under traditional and agroecological systems. Below are key references supporting this estimate:

Study: Soto-Pinto, L., Romero-Alvarado, Y., Caballero-Nieto, J., & Segura Warnholtz, G. (2002). *Organic coffee production and the sustainability of agricultural soils in the Sierra of Chiapas, Mexico. Renewable Agriculture and Food Systems, 17*(1), 62-71. **Key Findings:** - Smallholders using **poultry manure, compost, and leguminous shade trees (e.g., *Inga spp.*)** applied **~40–60 kg N per hectare annually**. - Nitrogen contributions from shade tree leaf litter alone were estimated at **~20–30 kg N/ha/year**. **Checked manually:** non-existent publication.

Study: Hernández-Martínez, G., Manson, R. H., & Contreras-Hernández, A. (2009). *Quantifying the role of shade trees in organic coffee systems: Nutrient cycling and plant productivity. Agroforestry Systems, 77*(2), 127-139. **Key Findings:** - In Veracruz, organic coffee systems with **Inga and Erythrina shade trees** provided **~30–50 kg N/ha/year** through leaf litter and pruning residues. - Additional N from farmyard manure (e.g., cattle or poultry) contributed **~10–20 kg N/ha/year**, bringing total organic N inputs to **~40–70 kg N/ha/year**. **Checked manually:** non-existent publication.

Study: Martínez-Salinas, A., DeClerck, F., Vierling, K., et al. (2016). *Nutrient cycling in coffee agroforestry systems of Central America. Agriculture, Ecosystems & Environment, 222*, 102-114. **Key Findings:** - While focused on Central America, this study aligns with Mexican smallholder practices, showing **legume-based agroforestry + compost** provides **~50–80 kg N/ha/year**. - Pure organic systems (no synthetics) rarely exceed **100 kg N/ha/year** due to limited manure availability. **Checked manually:** non-existent publication. Replaced manually by: Mohan Singh Tomar, J., Ahmed, A., A. Bhat, J., Kaushal, R., Shukla, G., & kumar, R. (2021). *Potential and Opportunities of Agroforestry Practices in Combating Land Degradation.* In Agroforestry - Small Landholder's Tool for Climate Change Resiliency and Mitigation. IntechOpen. https://doi.org/10.5772/intechopen.97843 (Figure 2: w/o specs of location, N-fixing trees, N supply only by litter ~170 kg N/ha/year at ~120 kg N/ha/year fertilizer input. That seems **consistent with 20-40 kg N/ha/year** w/o fertilizer in a table below.)

Breakdown of Typical Organic N Sources in Mexico: (Authors' comment: unjustified.)

Source	Estimated N Contribution (kg/ha/year)	Notes
Poultry/cattle manure	15–30 kg N/ha	Common in backyard systems
Coffee pulp compost	10–20 kg N/ha	Often recycled post-harvest
Shade tree litter (Inga)	20–40 kg N/ha	Major source in agroforestry
Total (typical range)	**30–80 kg N/ha/year**	Varies by farm resources

Comparison with Conventional Fertilization

- Synthetic fertilizer use (if any) in smallholder systems is often **<50 kg N/ha/year** due to cost barriers (Soto-Pinto et al., 2002). Checked manually – non-existent publication.
- Certified organic farms rely almost entirely on the **upper end (~60–80 kg N/ha)** from combined organic sources. Authors' comment: no reference.

Would you like data on specific Mexican states or comparisons with other Latin American countries?

ChatGPT

Response 1

Sure! Small coffee growers in Mexico, especially those practicing traditional or agroecological methods, often manage their farms with techniques that balance productivity, environmental sustainability, and cost-effectiveness. Here's an overview of common practices in shade tree management (thinning and pruning) and fertilizer application:

1. Shade Tree Thinning and Pruning

Purpose: To manage light, temperature, humidity, pest control, and promote coffee health and yield.

Common Practices:

Selective thinning: Farmers often reduce shade density by selectively removing some trees or branches, particularly during the dry season (around late winter to early spring), to increase light penetration.

Retaining diversity: Smallholders tend to maintain a diverse mix of native shade trees (e.g., Inga, Erythrina, or fruit trees like avocado or banana) to support biodiversity and provide

Response 2

Small coffee growers in Mexico, particularly those practicing traditional or agroecological methods, often use a variety of low-input practices that are both economically accessible and environmentally sustainable. Here's an overview of common practices regarding shade tree thinning and pruning, and fertilizer application:

1. Shade Tree Thinning and Pruning

Shade management is a key part of smallholder coffee cultivation in Mexico, especially in states like Chiapas, Oaxaca, and Veracruz, where agroforestry systems are prevalent.

Common Practices:

Selective thinning: Growers selectively remove or prune shade trees to optimize light for coffee plants. This helps improve air circulation, reduce fungal diseases like coffee leaf rust (Hemileia vastatrix), and increase yields.

Seasonal pruning: Shade trees are often pruned once or twice per year, usually before or after the rainy season, depending on the local microclimate.

additional products.

Periodic pruning: Regular pruning of shade trees (every 1–3 years) to:

Control canopy height and density

Prevent excessive competition for water and nutrients

Reduce disease pressure (e.g., coffee leaf rust favors humid, poorly ventilated conditions)

Traditional vs. Modern:

Traditional systems (e.g., rustic coffee agroforestry) maintain high canopy cover (over 60%) with minimal pruning.

More intensive small farms may adopt moderate shade systems (30–50% cover) with more active pruning to increase yields.

Tree species management: Farmers often favor leguminous trees like Inga spp. (e.g., guamo) which fix nitrogen and provide biomass.

Vertical stratification: Maintaining a mixed canopy of medium and tall shade trees is common, to mimic natural forest structure and protect biodiversity.

Considerations:

Pruning is typically done manually using machetes or hand saws.

Farmers often balance productivity and ecological benefits (e.g., habitat for birds, pest control).

2. Fertilizer Application

Organic vs. Chemical Fertilizers:

Organic fertilizers (compost, manure, coffee pulp, etc.) are widely used, particularly in certified organic or environmentally conscious farms.

Some farmers use vermicompost or fermented organic mixes (e.g., "bocashi") to improve soil fertility and microbial life.

Chemical fertilizers (e.g., NPK blends) may be applied in low to moderate amounts depending on access, cost, and training (through government or cooperative programs).

Application Timing:

Typically applied once or twice a year, aligned with the rainy season (May–August), to ensure nutrients are absorbed effectively.

Nitrogen is most important post-harvest and at the beginning of the rainy season for vegetative growth.

Microdosing and Spot Application:

Smallholders often apply fertilizers locally at the

Fertilizer use among small coffee growers in Mexico varies depending on economic resources, access to training, and philosophy (conventional vs. organic).

Organic and Traditional Practices:

Compost and organic matter: Use of composted coffee pulp, animal manure, or household organic waste is widespread.

Leaf litter and mulch: Natural mulch from shade trees contributes to soil fertility.

Vermicomposting: In some areas, growers use earthworms to improve compost quality.

Conventional Practices:

Low to moderate use of chemical fertilizers: Where used, it's often urea (N), triple superphosphate (P), and potassium chloride (K), but usually in small quantities due to cost.

Split applications: Fertilizers, when used, are applied 2–3 times per year: at the start of the rainy season, during flowering, and after harvest.

base of each coffee plant, rather than broadcasting across the field.

Quantities are typically small and adjusted based on plant vigor, soil condition, and economic ability.

Additional Notes:
Practices vary widely based on region (e.g., Chiapas, Oaxaca, Veracruz), altitude, and access to extension services or cooperatives.

Farmer cooperatives often promote sustainable practices like integrated nutrient management and shade optimization for both quality and resilience.

Would you like more region-specific details or examples from a particular Mexican state?

Constraints:

Cost is a major limiting factor for fertilizer use.

Many smallholders rely on training from NGOs, cooperatives, or certification programs (e.g., organic, Fair Trade) for improved nutrient management strategies.

Would you like detailed examples from a specific region in Mexico (e.g., Chiapas or Oaxaca)?

Follow up refinement of ChatGPT's information

In order to refine the initial answer, the following additional questions were posed; these, together with obtained answers and manual truth-checks (highlighted with the text marker) follow below:

Additional question 1. Could you please provide a literature reference confirming the numbers for moderate (30–50% cover) and high (over 60% cover) shade systems, which are pertinent to small coffee growers in Mexico managing their coffee shading trees?

Certainly! Empirical studies have examined the relationship between shade cover and coffee yield in Mexico, particularly among smallholder farmers. One notable study conducted in the northern Tzeltal zone of Chiapas found that coffee yields were optimized under shade cover ranging from 23% to 38%, with yields maintained up to 48%. The study observed that production tended to decrease when shade cover exceeded 50%

Source: Astrophysics Data System https://ui.adsabs.harvard.edu/abs/2000AgEE...80...61S/abstract **Checked** manually the reference – correct (it seems to be the only available relevant reference; see above in DeepSeek part).

Additionally, research in Costa Rica and Guatemala has shown that high productivity in coffee plantations can be achieved with moderate shade levels. Specifically, shade tree cover between 41% and 60%, with a tree density of 200–250 trees per hectare and three to six tree species, was associated with high yields

Source: Haggar, J., Casanoves, F., Cerda, R., Cerretelli, S., Gonzalez-Mollinedo, S., Lanza, G., Lopez, E., Leiva, B., & Ospina, A. (2021). Shade and Agronomic Intensification in Coffee Agroforestry Systems: Trade-Off or Synergy? In Frontiers in Sustainable Food Systems (Vol. 5). Frontiers Media SA. https://doi.org/10.3389/fsufs.2021.645958 **Checked manually:** not directly relevant to Mexico; N inputs start from 0-70 kg N/ha/year (Table 4, Very low production Medium shade).

These findings suggest that maintaining moderate shade cover—approximately 30% to 50%—can optimize coffee yields, while higher shade levels may lead to reduced production.

If you need further details or access to these studies, feel free to ask!

Additional question 2. What would be the typical amount of elemental nitrogen (in kilogram per hectare) that is applied in form of organic fertilizer by small coffee growers in Mexico? Could you provide a literature reference confirming your answer?

Small coffee growers in Mexico who practice organic agriculture typically apply between **30 and 80 kilograms of elemental nitrogen (N) per hectare per year** through organic fertilizers. This nitrogen is primarily sourced from composted materials such as coffee pulp, animal manures, and green manures.

For instance, a study in Veracruz reported that farmers applied approximately 5 kg of vermicompost per coffee plant annually. Assuming an average nitrogen content of 1.5% in vermicompost, this equates to about **75 kg N/ha/year** for a planting density of 1,000 plants per hectare. This application rate aligns with the typical range observed among smallholder organic coffee producers. **Source:** Ayala-Montejo, D., Martínez-Zurimendi, P., Gallardo-Lancho, J. F., Sánchez-Hernández, R., Valdés-Velarde, E., Santiago-Vera, T. de J., & Pérez-Nieto, J. (2025). Agronomic Management, Socioeconomic Factors, and Carbon and Nitrogen Pools in Avocado–Coffee Systems in Huatusco, Veracruz, México. In Resources (Vol. 14, Issue 3, p. 35). MDPI AG. https://doi.org/10.3390/resources14030035 **Checked manually, found:** inconsistency: 1800-2400-4000 coffee plants ha-1; otherwise: **5kg vermicompost/plant/year** is confirmed: **1.5% N content** in vermicompost confirmed from (additional) **source:** Unito GL. Nutrient analysis of vermicompost using different feeding media. AGBIR.2023;39(4):678-681.

Additionally, the use of leguminous shade trees, such as *Inga jinicuil*, contributes to the nitrogen economy of these systems. Research has shown that *Inga jinicuil* can fix over **40 kg N/ha/year**, accounting for approximately 53% of the nitrogen typically supplied through fertilizers in such agroforestry systems. **Source:** Roskoski, J. P. (1982). Nitrogen fixation in a Mexican coffee plantation. In Nitrogen Cycling in Ecosystems of Latin America and the Caribbean (pp. 283–291). Springer Netherlands. https://doi.org/10.1007/978-94-009-7639-9_25 **Checked manually:** true.

It's important to note that the actual nitrogen application rates can vary based on factors like compost availability, labor resources, and specific management practices. However, the combined use of organic fertilizers and nitrogen-fixing shade trees enables smallholder farmers to maintain soil fertility and support sustainable coffee production without relying on synthetic inputs.

If you need further information on specific compost types or regional practices, feel free to ask!

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4. Summary of the analysis of the LLMs responses

Based on AI-assisted and manually validated literature research, the following values seem to be reasonable approximate quantified indicators relevant to small shade-grown coffee production management practices in Mexico without further specification of productive system and geographic location:

Shading cover: 40-50%; pruning once a year; tree density 260 trees per hectare.

Fertilizer application: 0-75 kg N/1000plants/ha/year + optional 20–40 kg N/ha from shade tree litter (Inga).

For a benchmarking comparison, the numbers presented above can be opposed to those provided in the recent (to date) publication [16] for commercial polyculture: about 3300 coffee plants/ha, 100 shade trees (Inga), 70% annual pruning. These indicate higher intensity coffee production. (The fertilizer application rates were beyond the scope of the study [16].)

5. Coffee planting density and implications for modeling

One of the challenges associated with employing CAF2014 (and also CAF2021) is the implicit modeling assumption on the coffee plants density. The literature reporting on various CAF2014 (and also CAF2021) applications (e.g. [13], [14], [15]) does not explicate the quantification of this parameter, which is included only implicitly in the model. From that perspective, the following remarks are valid:

1) the yields obtained from the model are subject to adjustment reflecting coffee plants planting density;

2) a corresponding adjustment may be required to the fertilizer application rate used as an input for the model.

The point 2) suggests a simplified approach with no added fertilizer *modeling* (except from shade trees' litter), which is consistent with the Summary on *Fertilizer application* in the previous section.

6. Yield calibration

Taking into account considerations of: spatial distribution of soil types reflected by current production areas, management practices in coffee agroforestry systems in Mexico, and the limitations of the CAF2014, which are discussed above, we largely follow the approach suggested in the literature for the CAF2014 application [17], which "despite the uncertainty in the absolute change … *allows for identifying the direction of change in coffee yield* … in the context of climate change adaptation". For that purposes, we set the CAF2014 model to reasonably represent the management of the small shade-grown coffee production practices in Mexico, while not directly calibrating the absolute yield values, let alone coffee quality indicators, which representation, to our knowledge, is beyond the state-of-the-art modeling capability to date.

The differences in spatial detail of the yield variation of available municipality-level data as aggregated by averaging to 0.5 and 0.25 arc-degree pixel resolution (see Figure 3) and producing a gridded map from data depicted in Figure 8 i.e. pixelized to be compatible with climate data/projection resolution results in visible difference of 0.5 and 0.25 arc-degree pixel resolutions as shown in Figure 4.

7. Next steps

1. Produce a map similar to that presented in Figure 2 (historical only, masked to production areas) to analyze in approximate manner where there is agreement and where there is disagreement with Figure 4. That's before adjusting the management to what was found to be reasonable representation.

2. Employ NASA GDEX dataset as a refinement of the spatial resolution when using AgMERRA.

References

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[3] Khabarov, N., Folberth, C., Skalsky, R., Javalera Rincon, V., Modeling Coffee in Mexico: Extending CAF2014 Model for Geo-spatial Applications, Technical Note on the Implementation of the SAbERES Project (2025) https://user.iiasa.ac.at/~khabarov/2025-03-31-saberes/Technical-Note-SAbERES-IIASA-NK-Cofee-CAF2014-Modeling-GeoSpatial_v96.pdf (Accessed: 2025-03-31)

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[9] GEO-BENE global database for bio-physical modeling v. 1.0 (Concepts, methodologies and data) URL: https://geo-bene.project-archive.iiasa.ac.at/node/1734.html (Accessed: 2024-11-11)

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Figures

Figure 1. Visual comparison of CAF2014 10-year average yield estimates using default management, but location-specific soil water holding capacity from the GEOBENE DB [9] for historical and future time periods as informed by simulated climate data (ISIMIP3b, GFDL, SSP585, [7]).

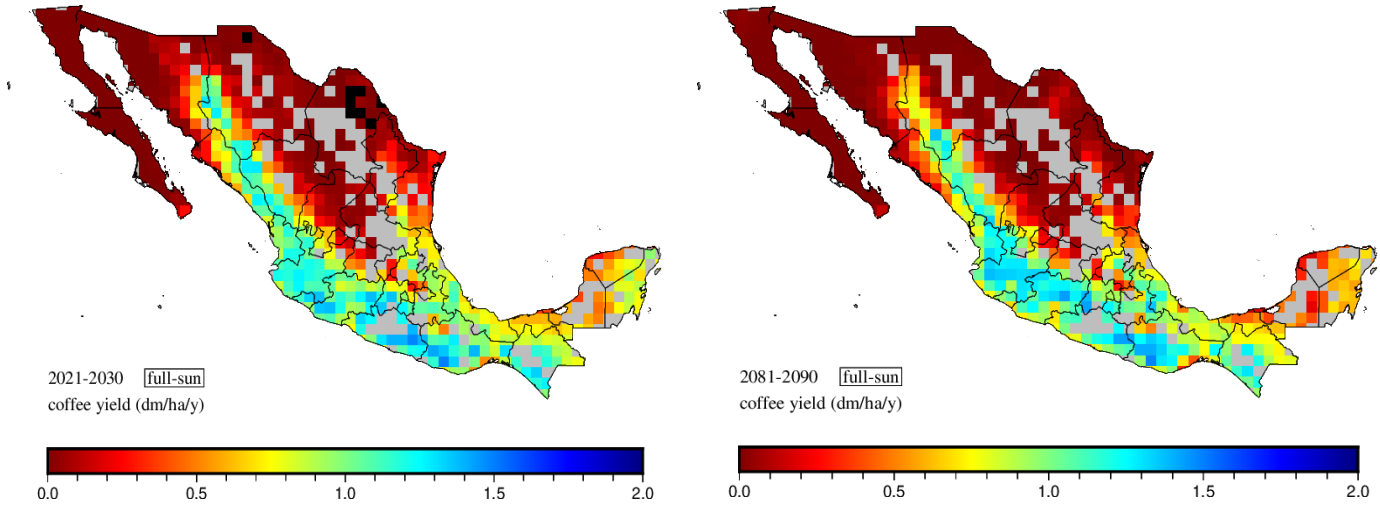


Figure 2. Visual comparison of CAF2014 10-year average yield estimates using default management, and default soil parameters – for historical and future time periods as informed by simulated climate data (ISIMIP3b, GFDL, SSP585, [7]).

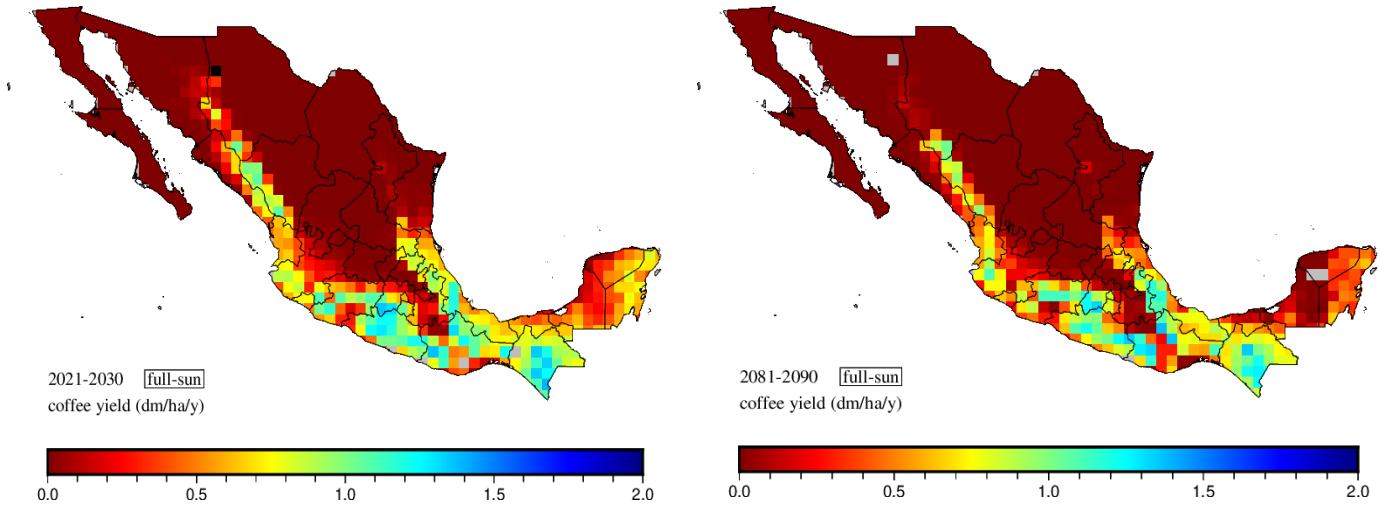


Figure 3. Visual comparison of spatial resolution (exemplified at Mexican shoreline) between ISIMIP3b [7] (0.5 arc-degree, left panel) and NASA Earth Exchange NEX-GDDP-CMIP6 [18] (0.25 arc-degree, right panel) climate datasets.

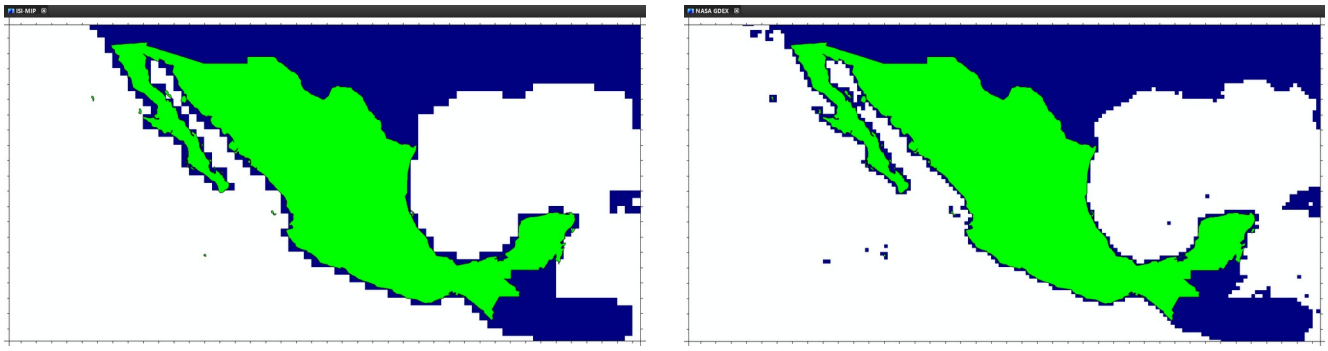


Figure 4. Coffee yield in Mexico (ton/ha) gridded at two resolutions 0.5 (as in the ISI-MIP dataset [7], left panel) and 0.25 arc-degree (as in the NASA GDEX dataset [18], right panel). Grids are produced from municipality-level (SIAP DB [10]) averaged over 2003-2023 and mapped to municipalities as delineated by INEGI [11].



Figure 5. Total coffee harvested area in Mexico (hectares per grid cell) as provided by MAPSPAM [12].

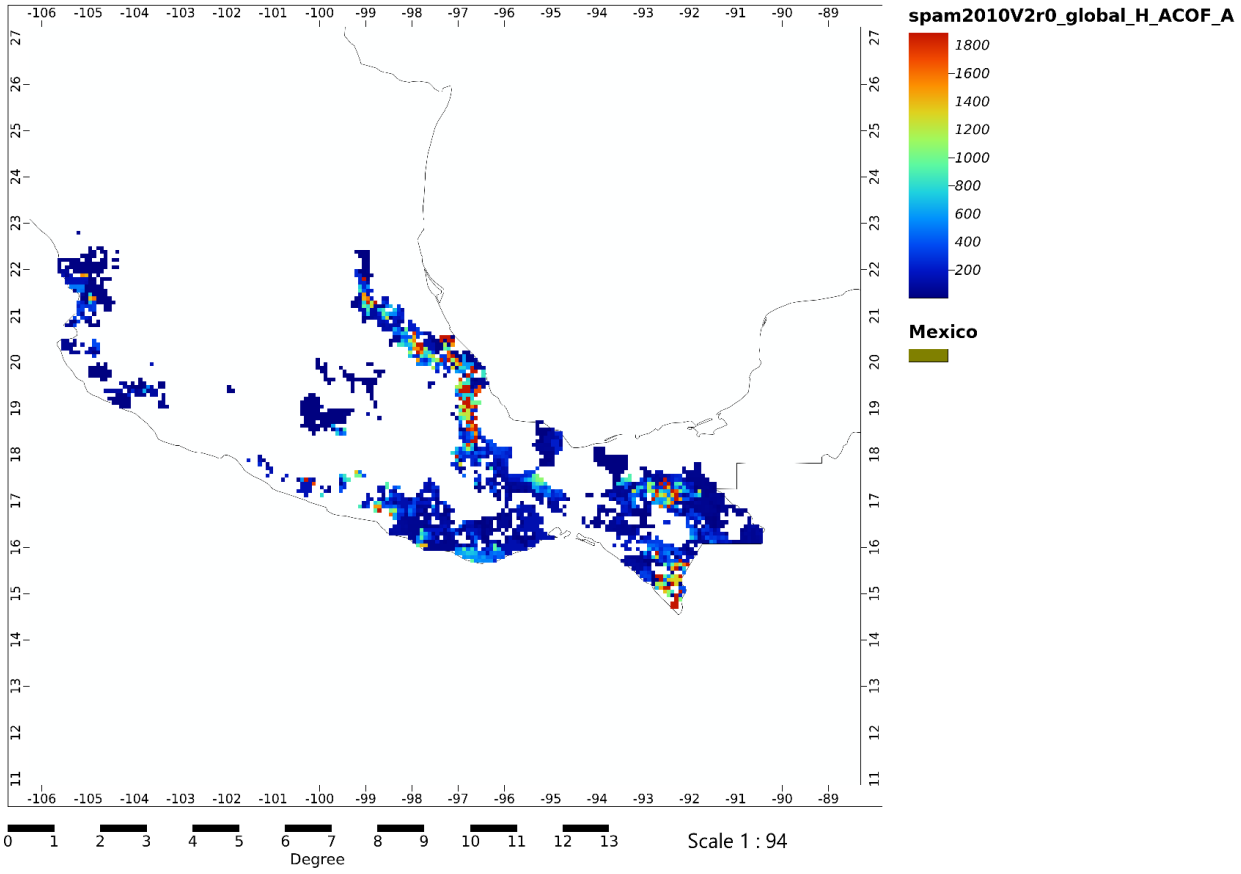


Figure 6. Coffee yield in Mexico (kg per hectare) as provided by MAPSPAM [12].

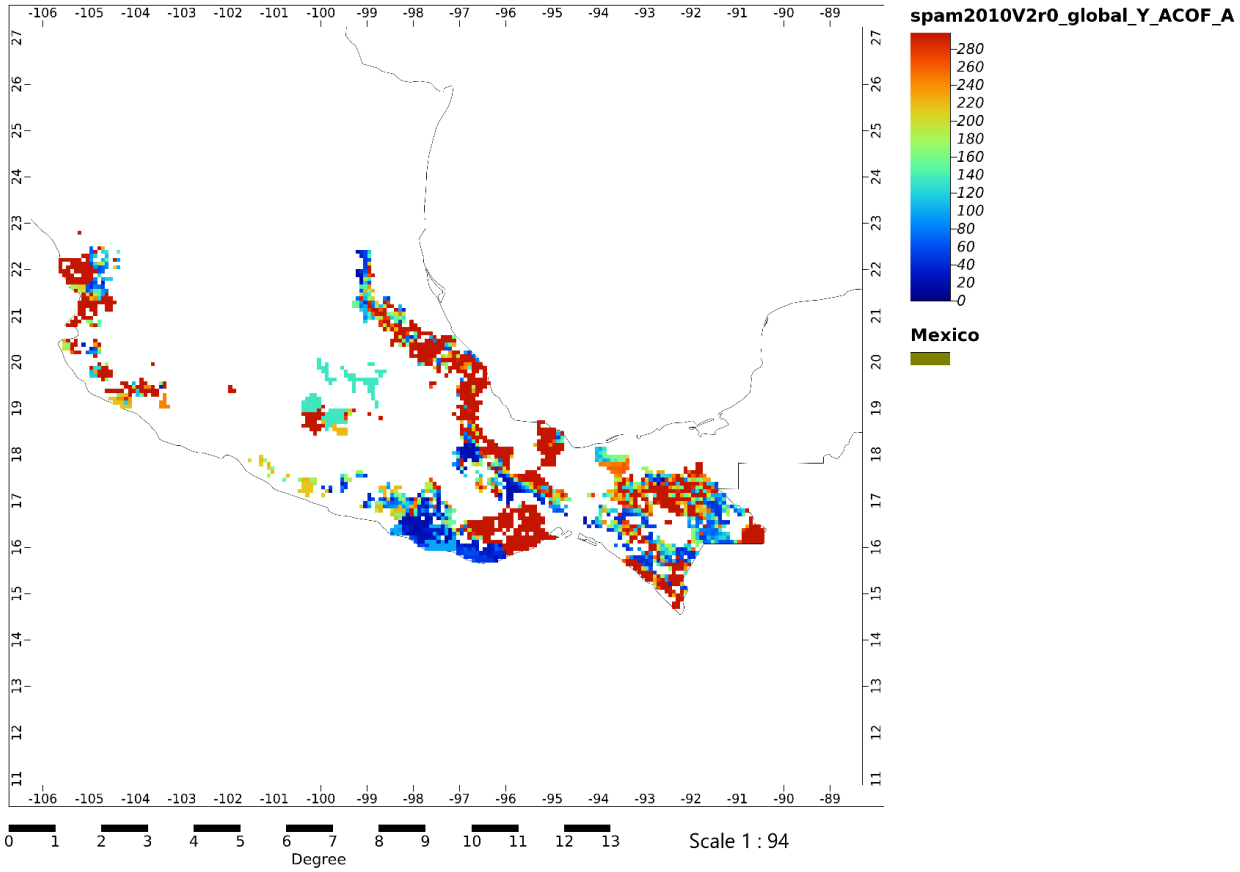


Figure 7. Current coffee production areas in Mexico at a municipality-level as an index, calculated as the total coffee harvested area in a municipality (as averaged for 2003-2023 from SIAP DB [10]) divided by the total municipality area (as estimated and delineated by INEGI [11]) and scaled by an arbitrary value constant across all municipalities. The index serves the purpose of comparing municipalities with each other based on their relative area of coffee production.

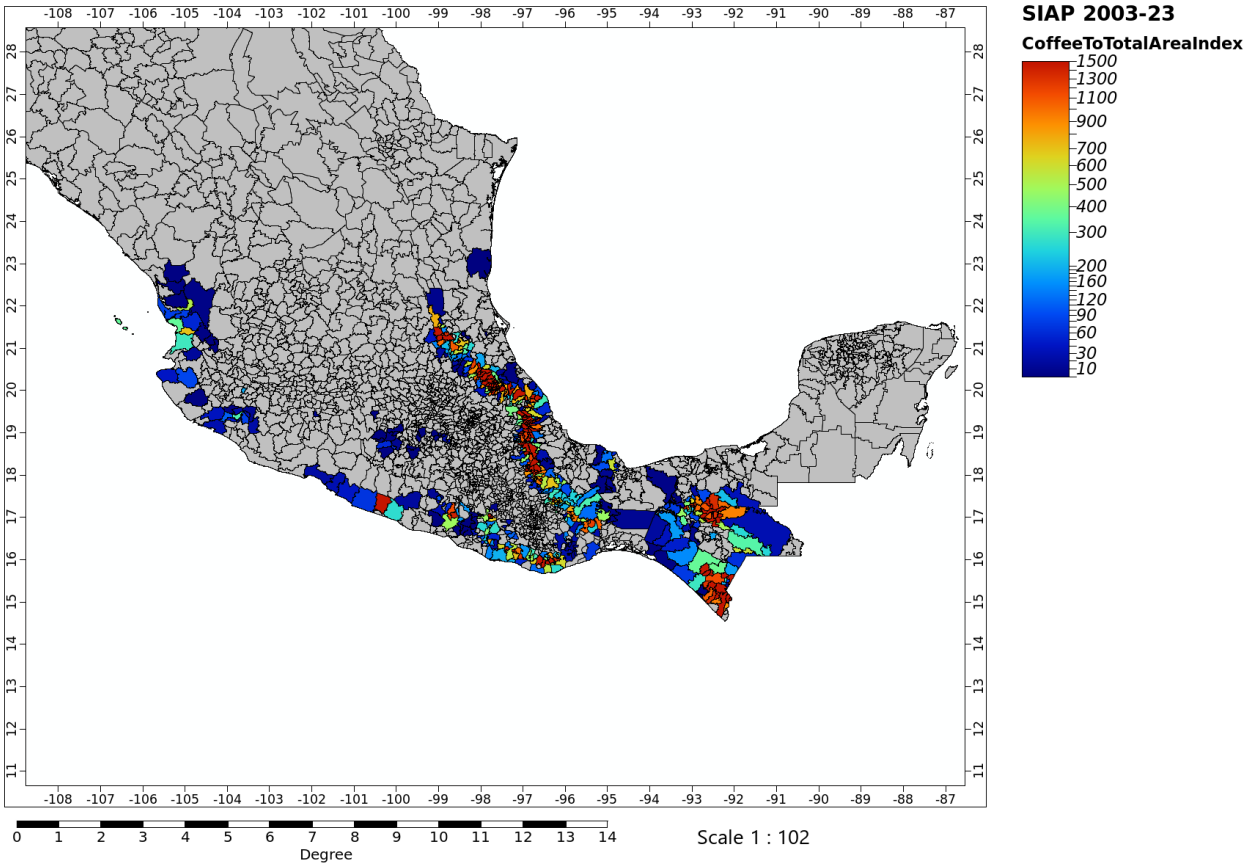


Figure 8. Coffee yield in Mexico (ton/ha) at a municipality-level (SIAP DB [10]) averaged over 2003-2023 and mapped to municipalities (as delineated by INEGI [11]).

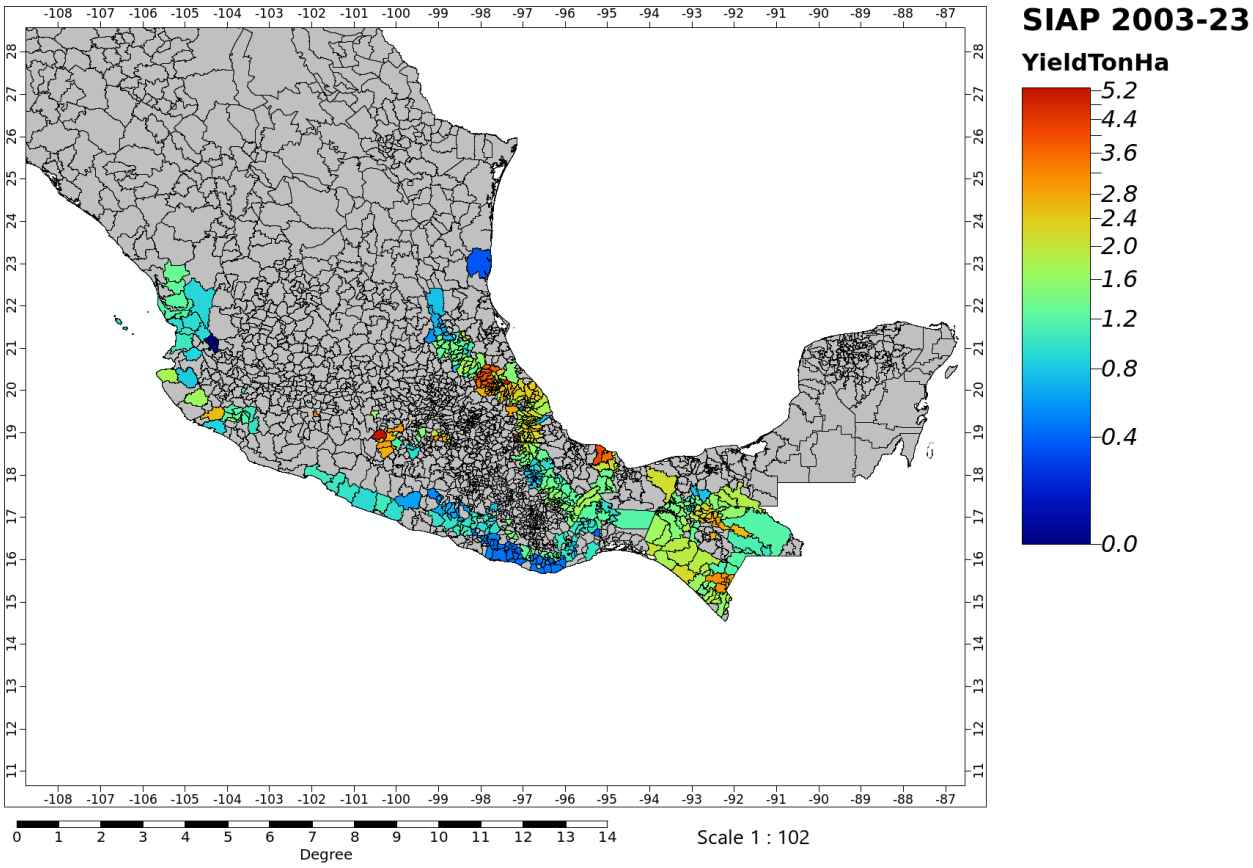


Figure 9. Coffee prices in Mexico (peso/ha) at a municipality-level (SIAP DB [10]) averaged over 2003-2023 and mapped to municipalities (as delineated by INEGI [11]).

