Synergistic garden ecosystems as climate stabilizers

A temperature analysis using the soil temperature Globe protocol

Alisia Mirti, Giorgia Davide, Giorgia Binucci, Gianmarco Caponi,
Tommaso Passeri, Damiano Piccardi, Noemi Pompili
Teachers Pietro Tozzi, Angela Bolis, Matteo Severini
Istituto Comprensivo Assisi 3
Italy
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1) **Abstract:**

This research aims to assess the temperature dynamics within a **synergistic garden** (syntropic garden) to investigate its role as a temperature stabilizer and enhancer of **soil biodiversity** in the face of climate change. Employing the Globe Soil temperature Protocol, we measured and analyzed temperature variations at different locations within the garden, seeking to understand how this agroecological approach influences microclimate regulation.

Objectives of our research are:

- evaluate the synergistic garden's effectiveness in regulating temperature compared to surrounding school grounds.
- identify potential correlations between specific land uses and microclimate variations.
- investigate how the garden's design and composition contribute to temperature stability.
- examine the broader implications of temperature regulation for the overall biodiversity and ecological health of the synergistic garden.

By examining the synergistic garden's ability to resist **temperature fluctuations**, we aim to provide insights into its potential as a sustainable solution against climate change. Furthermore, we explored the correlation between the garden's temperature regulation and the enhancement of soil biodiversity, contributing valuable information for the development of resilient agricultural practices in the context of a changing climate.

To achieve this, temperature measurements was conducted at multiple points within the synergistic garden using the **Globe Protocol**. Simultaneously, corresponding measurements was taken in different sections of the school grounds with varying degrees of exploitation, such as paved areas, lawns, and natural vegetation.

We identified sites where water was accumulating, and we addressed the issue by seeking locations with less water and less susceptible to atmospheric currents that could potentially affect our measurements.

This approach allows for a comprehensive analysis of temperature variations in relation to the specific characteristics of each land-use type.

We observed that in the synergistic garden, there is less variability at a depth of 5 cm and 10 cm compared to other soils, confirming its buffering function under the conditions we examined. In the future, we should analyze the results during the summer season.

2) Research Questions:

Our research question is “has the synergistic garden any role as a potential microclimate stabilizer?”.

By comparing temperature data from the synergistic garden with that of the surrounding schoolyard, we investigated how different land uses influence temperature dynamics and sought to contribute to the understanding of sustainable landscaping practices in educational settings. The findings could have implications for optimizing green spaces within and around schools for enhanced ecological and educational benefits (E. Hazelip, 2014).

3) Introduction:

In recent years, the frequency of extreme weather events has surged, raising concerns about their profound impacts on ecosystems. Existing research has indicated that plant diversity plays a pivotal role in mitigating the consequences of climate change by enhancing plant productivity and bolstering ecosystem stability (Huang at al., 2023)

However, despite the recognized importance of soil temperature in governing essential ecosystem processes, a critical gap exists in understanding whether plant diversity acts as a buffer against soil temperature fluctuations during long-term community development. Motivated by the existing gap in the literature, our research aims to extend these insights to a new context by investigating whether a similar cushioning effect is present in the synergistic garden ecosystem.

The unique characteristics of the synergistic garden, with its intentional mix of plant species and diverse planting strategies, provide an intriguing setting to explore whether the observed diversity-induced stabilization of soil temperature could contribute to mitigating the adverse impacts of extreme climatic events, such as soil carbon decomposition, and consequently, contribute to slowing down global warming. Through this study, we aim to bridge the existing knowledge divide and uncover potential applications of plant diversity for climate resilience in agroecological systems, specifically within the synergistic garden framework.

The story of our synergistic garden began in an inspired effort to breathe life into an otherwise barren expanse of soil, concrete, and debris. It was a long journey, that started in 2017, which led to an abandoned area becoming our current educational cloister where our synergistic vegetable garden is located. The uncultivated area consisted of an expanse of 100 square meters, between buildings used by the municipality, completely abandoned over time. The expanse was characterized by adverse conditions in order to cultivate and garden: first of all, the substrate is not made up of parent rock, but is composed by different types of inert material deriving from construction works, covered by a layer of soil 60-70 centimeters thick. This aspect alters the soil's textures and the biochemical balance in it, with the consequent effect of rapid loss and the need for fertilizer additives to cultivating. Another adverse condition comes from the soil texture in which the clay fraction is prominent and this leads to rapid compaction and poor permeability.

Parameter	Mesure	outcome	interpretation
Fine earth	%	94	
Stone frame	%	6	
Coarse sand	%	11,1	
Fine sand	%	22,7	
silt	%	35	
clay	%	31,2	
texture	-	-	clayey loam
pH	pH unit	8,2	Alkaline soil
Soil's texture measurement by Dipartimento di Ingegneria Civile ed Ambientale Laboratorio di Chimica Agraria Chimica delle Biomasse di Uso Agrario, Università di Agraria, Perugia october 2017.			

Fig.1. Sifting the soil

Fig.2. Sand filtration and analysis

Fig.3. Ph measurement

Furthermore the soil was compact and infested with wild grasses and important clearing and reclamation works has to be done for the first farming.

Fig.4. Uncultivated area

Fig.5. Reclamation works phase 1

For the first 2 years, various learning activities were designed by our teachers and pupils in order to improve green skills and the inclusion of pupils with various fragilities.

After the COVID period, the project for this area was completely renewed and redesigned. First of all the area was divided into four equal parts by perpendicular walkways, in which stable agricultural settings were started: half for the educational garden and half for the synergistic vegetable garden.

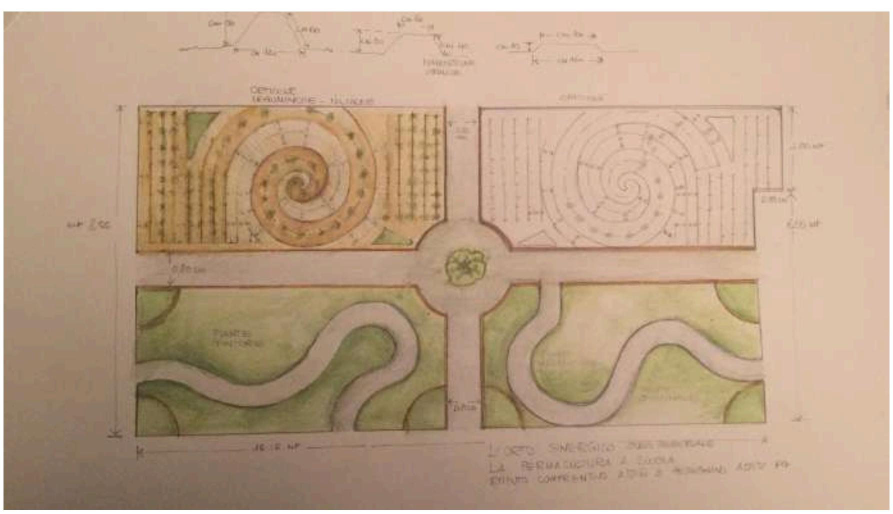


Fig.6. The new project

The new project had several aims to reach:

1. Enhance biodiversity
2. Protect the balance in the pedosphere
3. Reduce the impact of weeds
4. Try not to use any kind of chemical additive
5. Try no to move the earth
6. Build an outdoor laboratory space for observation, farming and storytelling
7. make the area usable in all weather conditions
8. Make the area accessible for all the pupils

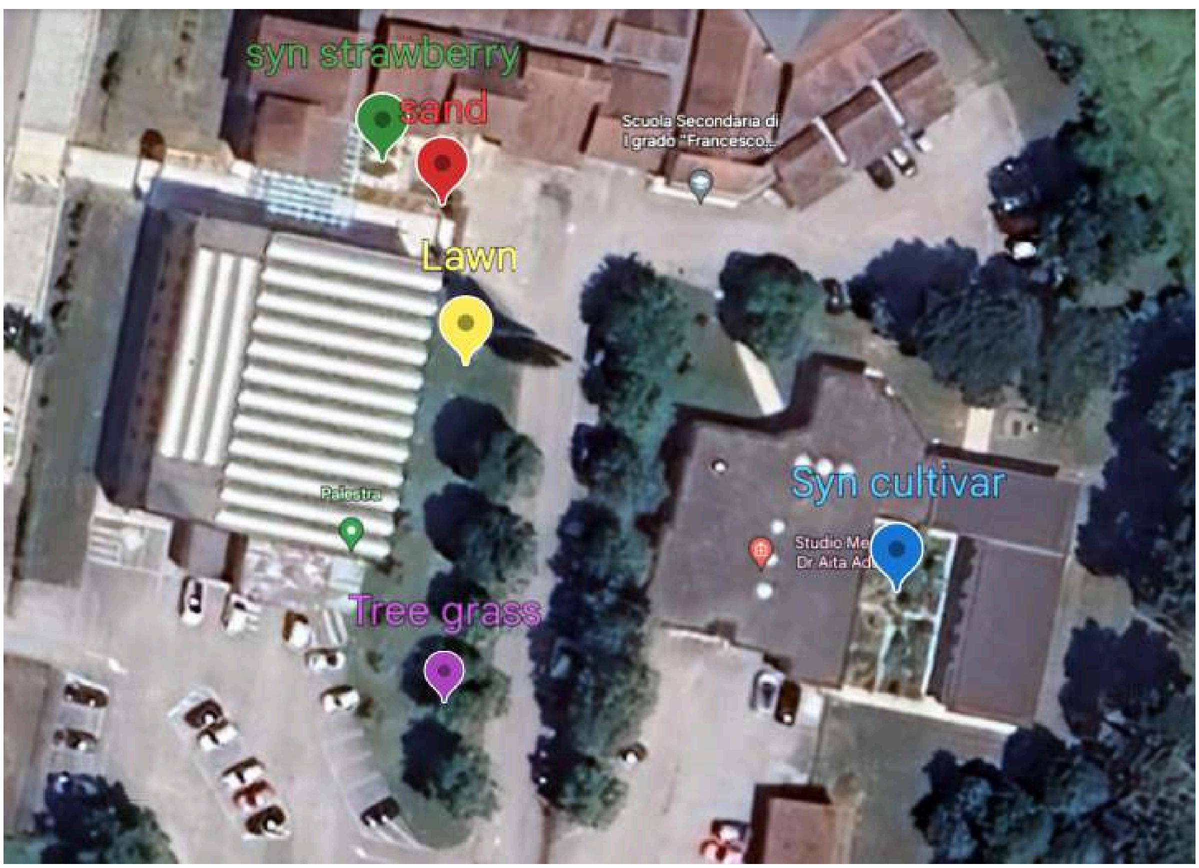
The synergistic garden was the hardest project to realize, trying to envolve the pupils in each part of the work. First of all we tried to "draw" in the soil our project and to build the soil rises that took such a big amount of earth to pile up and reach the height of 60 cm. Then we install the automated irrigation system in every part of the vegetable garden and, finally, we covered the soil with an organic substrate made by straw or hay. This project exemplifies the potential for environmental regeneration, showcasing how a neglected space can be revitalized into a thriving agroecological oasis. The initial challenge involved converting solid concrete and debris-laden terrain into arable land, laying the foundation for the subsequent establishment of a flourishing synergistic garden.

The garden is not merely a physical space but a dynamic educational tool. It provides a hands-on learning experience for students, teaching them about sustainable agriculture, ecosystem dynamics, and the importance of biodiversity. Additionally, the garden serves as a focal point for community engagement, bringing together students, teachers, and local residents in a shared commitment to environmental stewardship


Fig.7-8. Synergistic garden

4) Research Methods:

To pursue our research, students initially selected soil temperature monitoring sites to compare temperature variations between the synergistic garden and other representative soil types in the vicinity of Assisi 3 Middle School, within the comprehensive institute. Following the Hobo data logger protocol for measurements at 5 cm and 10 cm depths, 15 measurements were taken at each site under cloudy weather conditions, ranging from 6°C to 16°C. The students recorded the data in a spreadsheet and subsequently processed the information. To compare the values obtained at the selected sites, average temperatures were used.
The selected sampling sites are indicated with placeholder colors and distinct labels in the image below, captured using Google Earth:
1- *syn cultivar* is synergistic cultivated garden
2- *syn strawberry* is synergistic soil with only strawberries
3- *sand* is soil with imported sand
4- *lawn* is soil with grass
5- *tree grass* is soil near the grass



Map 1. Map of the site situated in Petrignano di Assisi, Italy. 43°06'15"N 12°31'58"E, 214m a.s.l.

Fig.9. Syn cultivar

Fig.10. Syn strawberry

Fig.11. Tree grass

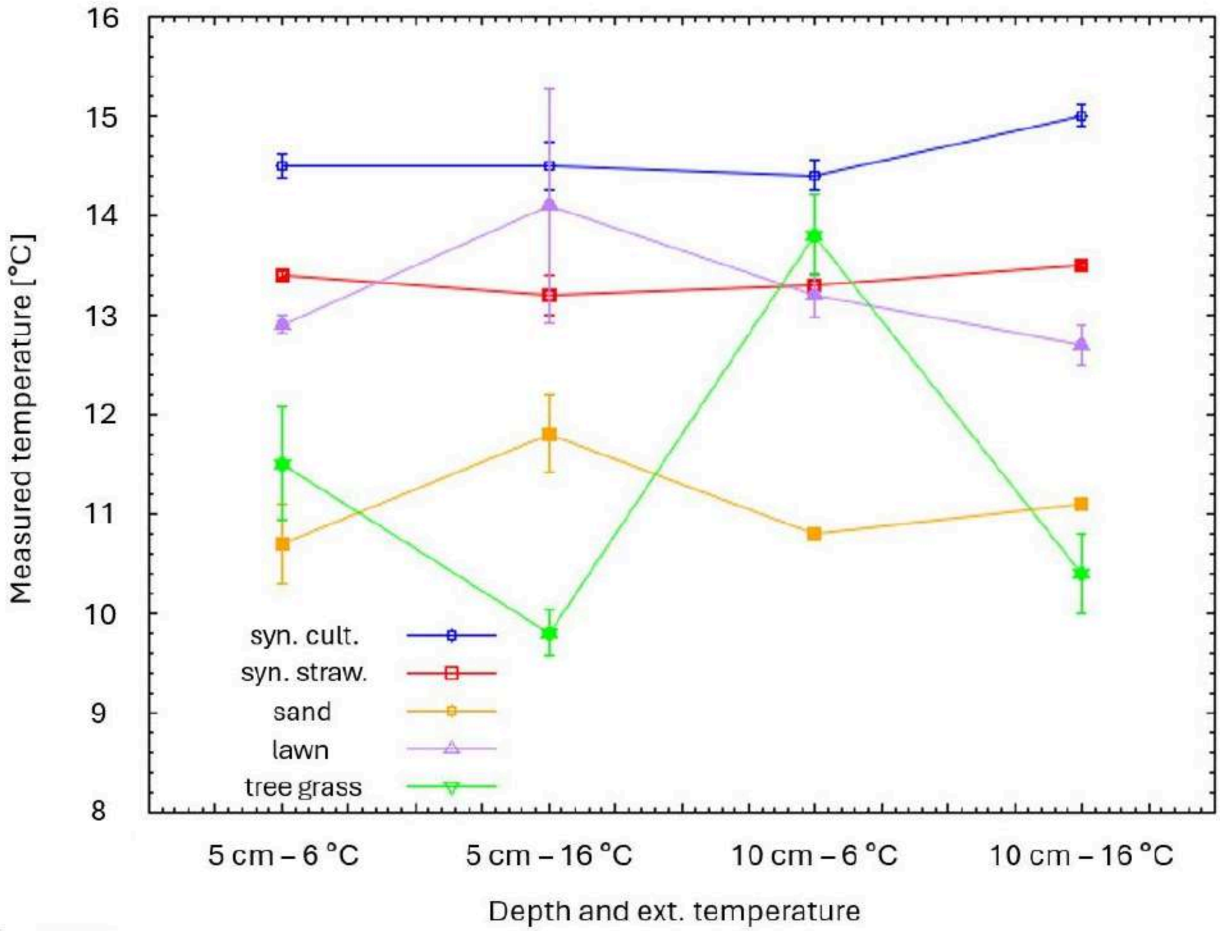
Fig.12. Sand

Fig.13. Lawn

5) Results:

In cloudy weather conditions from the analysis of the average data, it is evident that the cultivated synergistic soil exhibits a less variable trend under different temperature and depth conditions, particularly at a depth of 5 cm, at the depth of 10 cm the temperature difference is around +/- 0.5°C between air temperatures of 6°C and 16°C.
For the synergistic garden with strawberries, the variability is very similar even though the temperature remains lower compared to the cultivated synergistic garden.
For the sand, there is a difference of - 1 degree at 16°C between 5 and 10 cm,
for the lawn, the difference is -1.4 degree at 16°C between 5 and 10 cm.
The tree grass shows an increase in temperature of 6 degrees between 5 and 10 centimeters at 6°C and 0.6 degrees between 5 and 10 centimeters at 16°C:

	Result 5 cm T ext 6°C	Result 5 cm T ext 16°C	Result 10 cm T ext 6°C	Result 10 cm T ext 16°C
Syn cultivar	14,5	14,5	14,4	15
Syn strawberry	13,4	13,2	13,3	13,5
Sand	10,7	11,8	10,8	11,1
Lawn	12,9	14,1	13,2	12,7
Tree grass	11,5	9,8	13,8	10,4



Tab. 1. Graph 1. Average measurements

6) Discussion:

Our data have demonstrated that synergistic soil is the one that stabilizes temperature by reducing variability.

Surprisingly, contrary to our expectations, the temperature at a depth of 10 cm did not uniformly rise across all soil types; instead, it increased for sand and grass. We attribute this anomaly to the unusually rainy winter months during our sampling period. It would be prudent to monitor this trend as air temperatures rise, as it may provide further insights into the dynamics of soil temperature fluctuations.

However, it is important to acknowledge a significant challenge in the cultivation of our synergistic garden – the chemical composition of the soil. The initial pH measurement of 8.2 at the project's outset exceeded the optimal pH range for cultivation, which is typically between 6.5 and 7.3. It is imperative to reassess the current pH level of the soil to ascertain whether adjustments are necessary to align with optimal growing conditions.

Additionally, our synergistic garden has encountered issues related to pest infestations, posing potential risks to human health. Addressing these pests becomes a critical aspect of managing the garden effectively. Future endeavors in synergistic cultivation should consider implementing measures to control and mitigate these risks, ensuring a sustainable and healthy environment for both the crops and human consumers.

7) Conclusion:

In conclusion, our research on synergistic cultivation has provided valuable insights into the temperature maintenance capabilities of this soil type under various conditions. The data from our sampling clearly support the hypothesis that synergistic soil exhibits a remarkable ability to sustain temperature, showcasing the biodiversity within and contributing to reduced carbon degradation. The stability of subsurface temperatures in synergistic soil plays a crucial role in mitigating temperature-related carbon loss.

While our synergistic garden demonstrates promising features such as temperature stability and biodiversity, addressing challenges like soil pH and pest control is crucial for the continued success of this innovative cultivation method. Our findings underscore the importance of ongoing monitoring and adaptation to ensure the long-term sustainability of synergistic farming practices.

8) Bibliography/Citations:

Huang, Y., Stein, G., Kolle, O. *et al.* Enhanced stability of grassland soil temperature by plant diversity. *Nat. Geosci.* 17, 44–50 (2024). Enhanced stability of grassland soil temperature by plant diversity | Nature Geoscience

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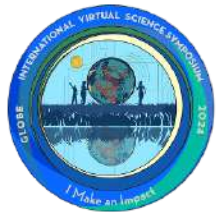
9) Badge Descriptions/Justifications:



BE AN IMPACT

This project was carried out by students during both curricular and extracurricular hours, with the collaboration of multiple teachers. The synergistic garden was created with the assistance of local farmers and holds significance in the context of agriculture for the conversion of unused land in the area.

BE DATA SCIENTIST

The report incorporates a thorough examination of data collected and processed by Reflection Question - If applicable, please describe how your report incorporates local knowledge systems (ie. Indigenous knowledge).students using spreadsheet software, aiming to determine the mean value and standard deviation. Additionally, students engage with data sourced from the Department of Civil and Environmental Engineering, Laboratory of Agricultural Chemistry, Biomass Chemistry for Agricultural Use. They critically evaluate the limitations of these datasets, draw inferences about historical, current, or future events, and leverage the data to address questions or resolve issues within the represented system.

BE A STEM STORYTELLER

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