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2 **Greenhouse cultivation for more sustainable food systems**

3 *Jay Ram Lamichhane*

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5 **Society must revisit the currently dominant agricultural model, based on agricultural expansion and**
6 **intensification. Greenhouse cultivation represents a promising alternative, particularly in the Global**
7 **South.**

8 Greenhouse cultivation represents one of the most efficient agricultural models to ensure high yields and
9 quality of locally-produced fresh products with the possibility to extend crop growing seasons¹. This high
10 efficiency results from a partial or total control of adverse abiotic or biotic stresses, including excessive heat
11 or cold conditions, optimized carbon dioxide and light levels, maximization of land space (e.g. vertical
12 farming), limited biotic stresses (animal pests, diseases and weeds), and optimized irrigation or ferti-
13 irrigation¹. Greenhouse cultivation can therefore contribute to reduce food insecurity, especially across the
14 Global South, thanks to the possibility of obtaining relatively high income by growing profitable crops to
15 secure the livelihood of both rural and urban families. In addition, for many high-value field crops,
16 greenhouse cultivation allows nursery raising to produce seedlings to be transplanted more later under
17 open-field conditions with possibility for early field harvest, which brings an important added value for
18 farmers who can sell off-season products at higher prices on the market. A wide range of technologies and
19 materials can be employed for greenhouse construction, going from low-tech polyethylene films generally
20 used for small-scale farming to high-tech glasshouses employed for precision farming. Likewise, depending
21 on the greenhouse cultivation technique and species to be cultivated, plants can be grown in soil or soilless
22 substrates (making it possible to use unfertile, degraded, polluted or otherwise unsuitable land for open-
23 field farming to grow food on an industrial scale).

24 Unlike relatively robust global statistics of open-field farming, no precise information exist to date on the
25 global area for greenhouse cultivation. In particular, there is paucity of information as to whether the global
26 extent and the expansion of greenhouse cultivation follow the same pace of global population with a
27 particular emphasis on the Global South.

28 Now writing in Nature Food, Tong and colleagues² present a global assessment of greenhouse cultivation
29 coverage in the 21st century. By coupling commercial nanosatellite imagery and artificial intelligence
30 techniques, the authors mapped 1.3 million hectares of greenhouse infrastructures in 2019 across 119
31 countries, which is a much larger extent than the previously estimated one³. They found large and small-
32 scale greenhouse infrastructures both in the Global North and the Global South with the latter having 2.7
33 times higher greenhouse coverage than the former. More specifically to the Global South, the authors found
34 a striking expansion of greenhouse cultivation in China, which accounts for 60% of the global coverage,
35 followed by Mexico and Morocco. For the Global North, Spain followed by Italy and Turkey are major
36 countries in terms of the global greenhouse coverage. Their study also highlighted extensive greenhouse
37 cultivation both across urban and rural areas of the Global South including China, with over 50% of
38 greenhouse cultivations located across regions characterized by substantial resource constraints, including
39 water scarcity that represents a key limiting factor for open-field cultivation. However, the study by Tong and
40 colleagues did not differentiate between the types of covering materials used for greenhouse cultivation, a
41 point which deserves further investigation.

42 Tong and colleagues² found knowledge gaps in spatiotemporal datasets of greenhouse cultivation including
43 the duration of a given greenhouse cultivation coverage. For this reason, their analysis also included
44 greenhouse cultivation that persisted only one year. The knowledge gap in the literature on annual land
45 use changes in terms of greenhouse cultivation raises concern on the stability of the mapped greenhouse
46 cultivation coverage over time, especially for low-tech infrastructures that are widely present in the Global
47 South.

48 While the work by Tong and colleagues² emphasizes the potential of greenhouse infrastructures to enhance
49 global food security, their study also raises concern about potential negative socio-economic and
50 environmental impacts of this greenhouse cultivation boom. The latter include reduced aesthetic values of
51 the landscape due to greenhouse cultivation clusters, overexploitation of water resources in drylands,
52 surface and groundwater contamination from excessive use synthetic pesticides and fertilizers,
53 contamination of soil, aquatic and terrestrial environments by plastic debris, soil degradation due to more
54 intensive and all year round farming practices, emissions of air pollutants and potential higher carbon,
55 energy and water footprints, especially the grey water footprint⁴, compared to open-field cultivation⁵⁻⁷.

56 The surge of greenhouse cultivation coverage in the Global South thus sounds an alarm bell and calls for
57 proactive policies to mitigate potential negative effects of this cultivation system. Some of these drawbacks

58 can be reduced by using more efficient energy-saving techniques based on waste valorization and resource
59 renewal. Detailed multi-criteria assessment and life cycle analysis studies that evaluate economic,
60 environmental and social cost-benefit analysis of greenhouse cultivation will be vital for decision-making in
61 national and regional public policy.

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67 **Competing interests**

68 The author declares no competing interests

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88 *Greenhouse cultivation of valerian salad in Sabaudia, Latina province, central Italy (Photo credit: Massimiliano*
89 *Natali)*