Carbon Sequestration in Soil as a Countermeasure against Global Warming and Improvement of Soil Productivity 2025/2050 Essential Key Targets of 'Plant Breeding 5.0'

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Alchemist Symbol for the Earth

Symbol for Climate Change

Japanese Symbol for Seed of Life

Symbol for Synthetic Biology

Symbol for Artificial Intelligence

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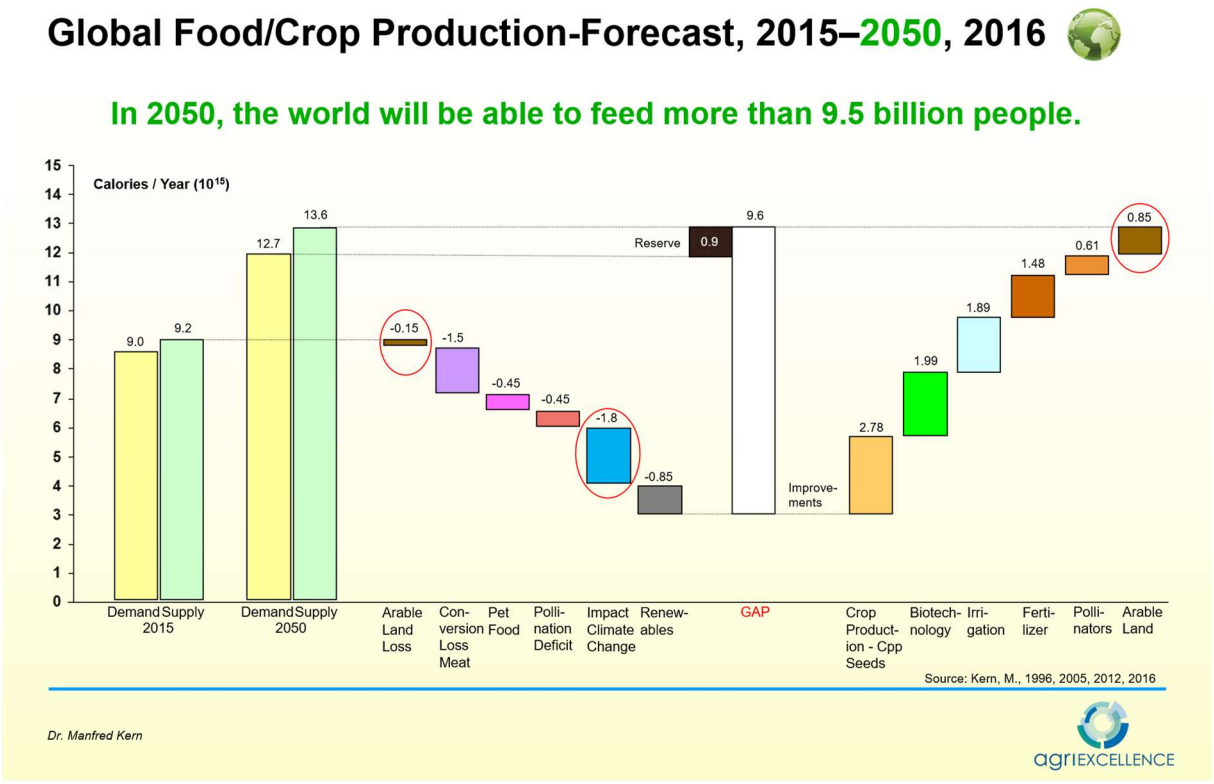
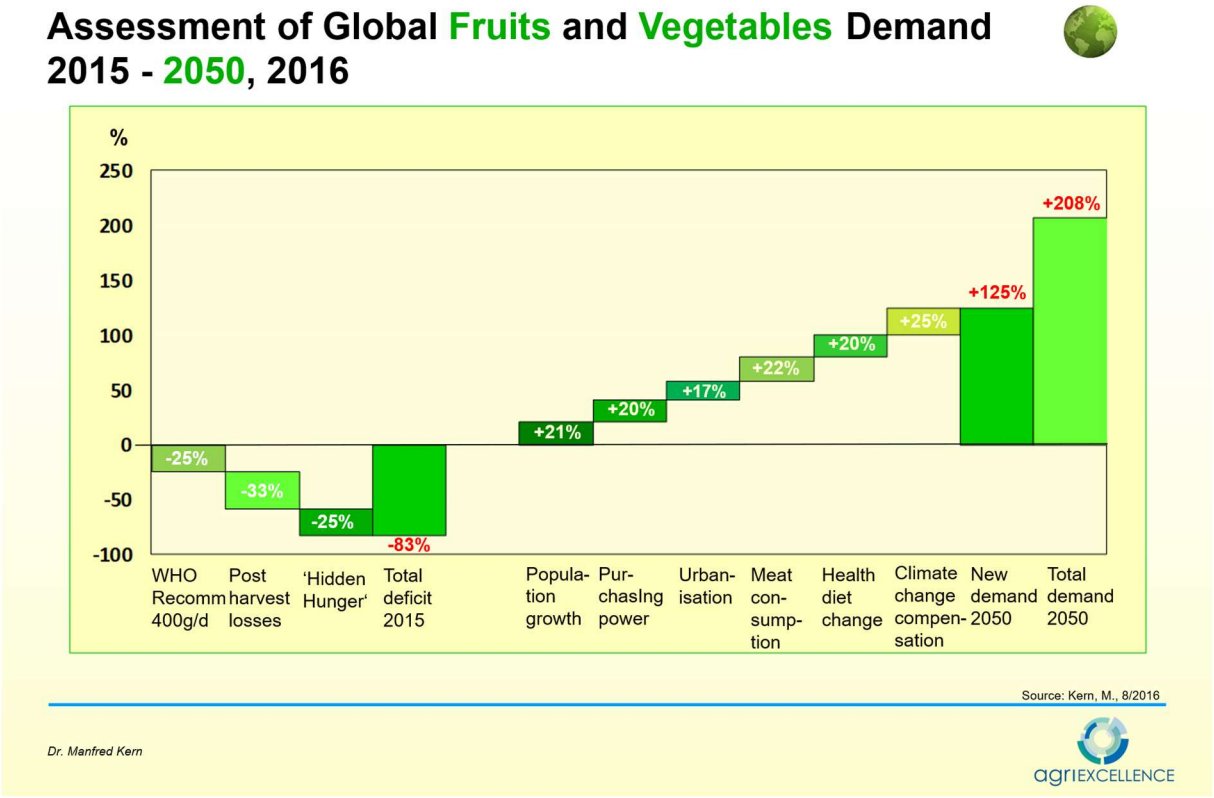
Well, it has to be considered, that between 2015 and 2050 more than a doubling of crop production, a nearby doubling of meat production, a tripling of plant-based protein production (food & feed), and a tripling of fruit and vegetable production is necessary to feed 9.7 billion people living on earth in a healthy way (Kern, M., 2016a, b), and that climate change and other '*black swans*' such as soil degradation will make agriculture increasingly volatile.





1. **To meet these demands now and in the future, we need nothing less than a "second green ®*evolution*".** This is an essential necessity, because analyzed yield trends of key crops such as maize, rice, wheat and soybean are insufficient to double global production by 2050 outlined in detail by Ray et al. (2013). Current projections of crop yield from "CropBooster-P" (Harbinson, J. et al., 12/2022) **suggest we will fall 40-70% short of demand by 2050.**
2. **It is crystal clear; there is need for a second green ®*evolution* – a green ®*evolution* in agriculture.** While global demand for agricultural produce continues to rise, limited arable land, decreasing growth rates of crop yield, water shortages and climate change create enormous challenges on the supply side.
3. **We must eliminate global hunger as soon as possible.** For further information see: "***Food security at the crossroads – A Wake-up Call***" (Kern, M., 2012) and "***Food security at the crossroads – A Wake-up Call in 2012! / An Emergency Call in 2025!***" (Kern, M., 2025a), as well as "***Most of the 17 SDGs Are not on Track to Be Achieved by 2030***!" (Kern, M., 2025a).
4. **Climate change mitigation and adaptation are further key challenges at the beginning of the 3rd millennium** was adressed by the author in 2008. Many people tend to think of climate change as something that will impact the future, but warming over the past 20 years has already had real effects on global crop supplies. Between 1981 and 2002 higher temperatures have reduced the combined production of wheat, corn, and barley by 40 million tons per year. **Global warming is creating a drag on production of the world's leading food and feed crops, as well as of raw materials for biofuels.** Agriculture is the industry whose fate is most closely linked to climate. Land use change has to be avoided as much as we can, because the expansion of land area under cultivation presents a serious threat of increasing greenhouse gas emissions.

Consequently, the maintenance or increase of crop yields is necessary in any strategy for climate change mitigation and sustainable agriculture (Kern, M., 2008, 2010).
In 2025, Raza, A. et al. reported, that crop production losses caused by climate change events amount to **approximately 110 billion US dollars per year**. One third of crop losses are mainly caused by drought.
In 2024, according to Ritchie, H. yields in countries currently suffering from hunger are expected to decline. The injustice of climate change is that **those who are already the worst off will be the most affected**.
In 2024, Kotz, M. et al. projected, **that food prices will rise by 2035 caused by wheather extrems.** "In Africa, South America, and parts of Asia, they projected an **increase in food prices of 40 to 50 %**. These regions are expected to face the most severe inflationary pressures due to climate change. In contrast, regions like North America, Europe, and parts of Oceania exhibit lower (but still significant) projected increases in food prices, ranging from 30 to 40 %. This underscores the disproportinate impact of climate change on food prices in developing regions, exacerbating existing vulnerabilities and potentially leading to increased food insecurity."

5. **Approximately 15% of fossil fuels worldwide** were used in agriculture and food processing, retail and waste in 2024 (EID Food 2025, 2024). Global atmospheric concentrations of greenhose gases did reach a record of 37.4 Pg CO_2 yr^{-1}. **Soil carbon sequestratration** offers a natural and effective approach in reducing atmospheric CO_2 levels (Das, S. et al., 2025). This has to be improved as quickly as possible. Regardless of this, it is important to develop **fossil fuel-free farming (F^4) systems** in order to minimize major sources of CO_2 emissions and the acceleration of climate change (Kern, M., 2002, 2009, 2018, 2023, 2025).
6. **Well, with the increasing use of soil, there is a growing trend worldwide toward soil overuse and carbon depletion** (Kern, M., 2010). This affects **approximately 20-25%** of all soils globally.
7. **"Soil – is more valuable than gold!"** "We must recognize that soil has a higher value than gold. Unfortunately, the world does not yet appreciate this vital fact. For those who are farmers, soil is the source of our food, the very future of humanity. But for the urbanized world, soil is just dirt, mud and no-one has a proper understanding of it (Kern, M., 2008, 2010).
8. **"Seed is the basic agricultural input for and required for sustainable agriculture." Seed is in fact the hub** around which all other strategies to improve productivity resolve (Kern, 1999, 2000). **"Plants and plant crops have always been, and will continue to be, of vital importance for humankind."** "Improvements in the adaptability, physiological fitness, and photosynthetic capacity of crops are key factors for combating climate change and protecting productivity both now and in the future. All people working to improve seed quality have to rethink and refocus their breeding targets. A great deal of work is in progress in that direction in order to overcome abiotic stress factors using state-of-the-art technologies - hopefully in time. Drought-, flood-, and salt-tolerant plants must be developed. Conservation tillage farming must be implemented in order to reduce soil erosion and to retain soil moisture, as well as to reduce carbon emissions from the soil (Kern, M., 2008, 2010). Significant progress was achieved by 2025.
9. **Until now, plant breeding has always focused on** increasing yields, boosting biomass production, disease and pest resistance, improving nutrient content, cold resistance, adaptation to regional climate conditions, end-use qualities, etc.

10. **To protect the soil, sequester CO_2, and mitigate climate change,** plant breeding programs should rethink and focus on the following (Kern, M., 11/2025b):

- increase yield, e.g. produce more fertile ovaries and grains per floret in wheat (Schoen, A. et al., 9/2025)
- mitigate climate change without compromizing yield (Rizi, M. & Mohammadi, M., 5/2023)
- ensure crops maintaing their nutritional value while benefiting from accelerated growth (Acorn Horticulture, 7/2025)
- use the 'CO_2-fertilization' effect, to increase photosynthesis and biomass production
- overcome the 'dilution' effect, the reduction of minerals, nutrients and overall quality
- boost storage of soil carbon
- reduce carbon from atmosphere
- produce more and deeper roots (Rizi, M.S. & Mohammadi, M., 5/2023)
- store carbon in deeper soil layers
- be resilient under changing environments (e.g: draught and heat, water stress)
- improve N_2 fixation from the air
- improve water efficiency
- resist to phytopathogenic diseases; these are usually transmitted by vectors such as the cicada *Pentastiridus leporinus* (Hemiptera: Cixiidae) and include diseases such as *Stolbur phytoplasma* in sugar beets and potatoes, *Arsenophorus phytopsthogenicus* in sugar beets, potatoes, onions, or bacterial wilt in carrots and beetroot
- resist to micro- and nanoplastics in the soil and environment (Kern, M., 2024)
- protect plant carbon from microbes (Poffenbarger, H. et al., 3/2023)
- overcome the fact, that many crop varieties are more suseptible to biotrophic viral pathogens (e.g. soybean) (Sanchez-Lucas, R. & Luna, E., 3/2025)
- avoid weakening the plant immune systems
- maximize plant carbon fixation during fallow period (Poffenbarger, H. et al., 3/2023)
- identify and manipulate genes associated with suberin synthesis
- develop crops which are significantly synergized by biochar (Li, J. et al., 1/2025)
- develop crops which are significantly synergized by biochar plus microbial inocculants
- develop crops which are significantly synergized by biochar plus nano-encapsulation of biofertilizer (Markets and Markets, 5/2025)
- improve energy efficiency in biofuel crops by actively remove CO_2 from the atmosphere (Babbar, S. et al., 4/2025)
- improve cover crops such as CoverCress (Innovative Nourishing Tomorrow, 2/2020)
- transform annual crops to perennial crops, e.g. Kernza® grain, (Land Institute, USA, 5/2022), perennial rice (Zhang, S. et al., 11/2022)
- include understudied crops, orphan crops, landreaces, and crop wild relatives (Byrne, P.F., 2023)
- utilize relevant characteristics of C_4 plants to enhance the CO_2 absorption capacity of C_3 plants (Zhao, M. et al., 3/2025)
- design carbon storage crops

Yes, indeed, we need a **DNA-®*evolution* of Agriculture – a 'Second Green Revolution' in plant breeding** and **agriculture**. With '**Plant Breeding 5.0'** and '**Agriculture 5.0'** (Kern, M., 2025c) it is possible to create added value for agriculture by improving soil productivity, sequestering CO_2 from the atmosphere, combating climate change, reducing the carbon footprint, protecting the environment, improving the ecological-economic benefits for farmers and enabling sustainable life on Earth.

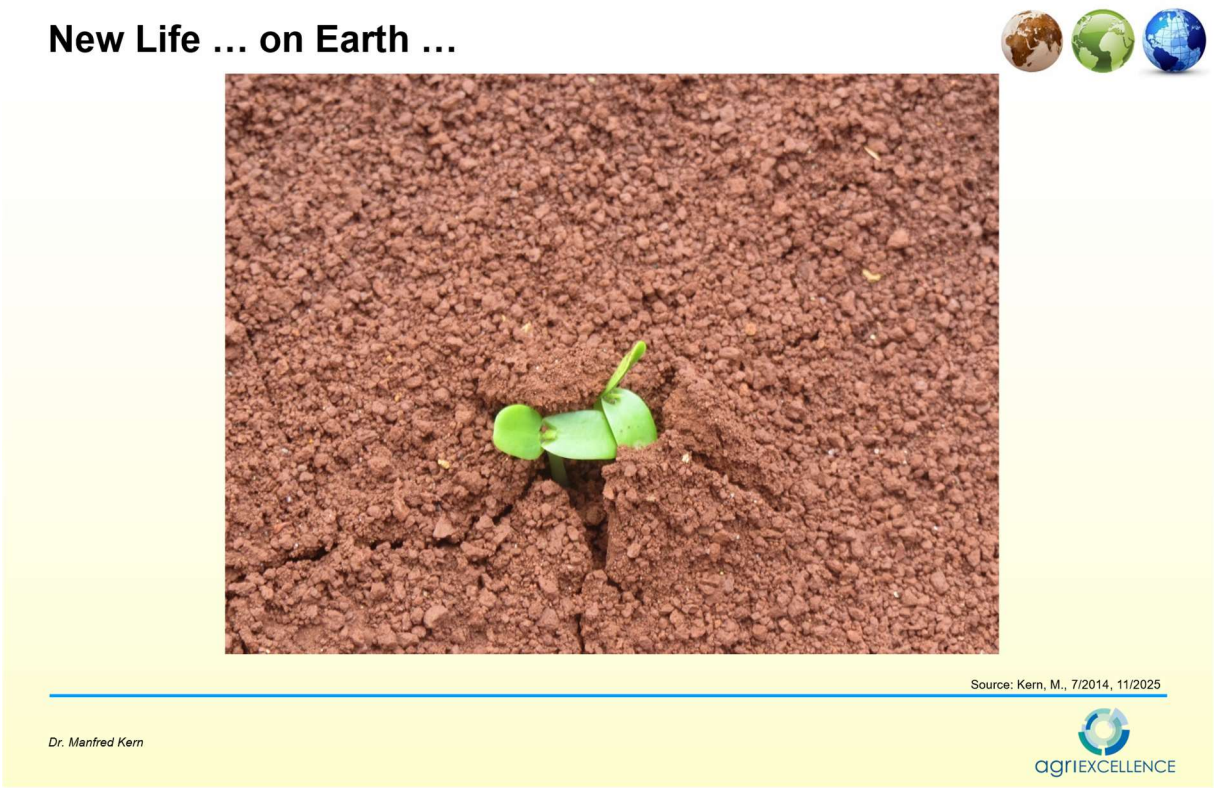
Finally, some food for thought:

- **"*Only the soil distinguishes the quality of seeds.*"** (Saint-Exupéry, A., 1939) or: **"*Only the seed distinguishes the quality of soil.*"** (Kern, M., 2002).

- **"*Quae sint in quoque agro serenada ac facienda, quo terra maximos perpetuo reddat fructus*"** Varro, M.T., *Rerum rusticarum* (First Century BC).
    - When he wrote these words, Marcus Terentinus Varro, a Roman landowner of the first century BC, was eighty years old and had recently merried. *Rerum rusticarum*, one of a number of Latin treaties on agriculture to survive to the present day, was written for his wife as a handbook of advice on how to run the estate he had purchased for her. In this passage he defines, fort he first time, the concept of sustinability.
    - He says: "***Agriculture is a science which teaches us what crops are to be planted in each kind of soil, and what operations are to be carried out in order to that the land may produce the highest yields in perpetuity***".

- Furthermore, let us not forget the following warning from **a piece of wisdom put into words 3.500 years ago**:
    - "***Upon this handful of soil our survival depends. Husband it and it will grow our food, our fuel, and our shelter and surround us with beauty. Abuse it and the soil will collapse and die, taking humanity with it.***" (From Vedas Sanskrit Scripture - 1500 BC).

- Last, but not least, let's reflect the author's ***Vision 2000-2050 - "To understand the dialogue of genes and carry it on further":***
    - ***"To decipher the primary language of nature, to marvel at it, to understand it, to open up its possibilities with a sense of responsibility, and to use it in an ethically acceptable way.***
    - ***... for without genes there can be no seeing, speaking, hearing, feeling or smelling - there can be no language, no communication, no dialogue, no art, no ethics, no morality - and no life.***
    - ***To use the primary language of Nature, or: How can we find the way from the secrets of life to ethically acceptable innovations for the future?"*** (Kern, M., 2000).



References are available on request.