Field of Biological Production, Ecology/Environment

Achievement : For outstanding contributions to estimation of global biospheric productivity and climate change science using advanced formulas based on observation

Prof. Christopher Field (USA)

Born: March 12, 1953 (Age: 68)
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Measuring photosynthetic and transpiration rates of living leaves

Plants absorb CO_2 in the atmosphere through photosynthesis and convert it into organic matter. However, a great variety of plants can be found on Earth, and the photosynthetic rate of each plant depends on the climate, the soil, its altitude, and other factors particular to the environment in which it grows.

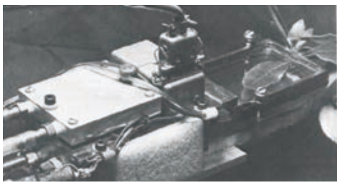
In the early 1980s, Field developed a device that could measure both photosynthetic and transpiration rates of leaves (see photos below). It allowed for the control of temperature, humidity, and CO_2 concentration to measure photosynthetic and transpiration rates of leaves under various conditions.

The most advantageous aspect of this device was its portability. Without that, plants would have to be gathered and brought to a laboratory, which affected the environment and biological activity, and therefore resulted in inaccurate data.

This device enabled researchers to analyze plants in-situ using the "living leaves" of plants rooted in the soil. They could then gather real data that reflected the growing environment, as there was no longer any need to collect or move the plants.

Field brought the device to various areas to gather a vast amount of data during his field surveys and experiments.

Equipment used to measure photosynthetic rate and transpiration of living leaves.



Analyzing a living plant leaf in soil.

The equipment can all be stored in a carrying case.

Field *et al.* (1982, *Plant, Cell & Environment*)

Leaf photosynthesis and stomatic function

Stomata are tiny pores found on the surface of plant leaves, and stomatal resistance is used to describe how easily CO_2 and water vapor pass through the stomata of a leaf. By incorporating Field's formulas for photosynthesis, it became possible to estimate the flow of CO_2 and water vapor between plants and the atmosphere.

Field continued to engage in theoretical research based in the data he gathered in his field surveys and experiments. He made it possible to describe complex plant phenomena in a quantitative way by expressing photosynthetic rate in leaves through a function that depends on temperature, light, atmospheric CO_2 concentration, leaf nitrogen level, and other factors.

Nitrogen has a significant influence on photosynthesis rate. Field revealed how photosynthesis rate depends on leaf nitrogen content and irradiance levels (see Fig. 1). This research has also contributed to agricultural efforts to improve the efficiency of nitrogen fertilizers.

Field's formulas were introduced into the climate models essential to understanding and predicting climate change caused by global warming.

CO_2 is extracted from the atmosphere through the opening and closing of the stomata, and water vapor drawn up from the roots is also released (see Fig. 2).

Field's equations were introduced into climate models, and with the addition of living plants, the carbon cycle – i.e. the interchange and flow of CO_2 between plants and the atmosphere and oceans – became a new part of the climate models.

This made it possible to answer questions such as how the rise in atmospheric CO_2 concentration and temperature affects plant growth and photosynthesis rates, and what sort of feedbacks are produced. That understanding led to the ability to predict future climate change through understanding the CO_2 cycle.

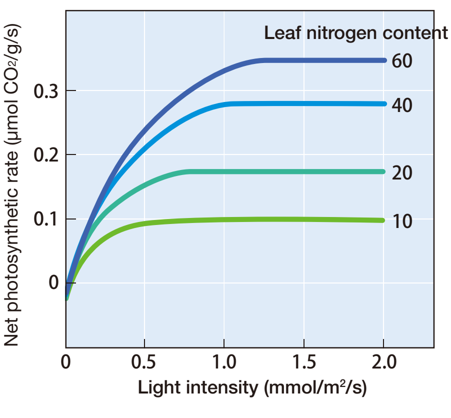
CO_2 absorption in the global biosphere

Field's formulas are based upon observational data, and were developed to treat plant ecosystems as a single, virtual leaf. Gaining a qualitative understanding of the environmental response of complex vegetation through these formulas was significant because it broadened the applicability of the analytical model to cover both terrestrial vegetation and marine biospheres.

In collaboration with Earth observation researchers at NASA and other organizations, Field used data gathered by observational satellites to estimate how much CO_2 is being absorbed by which vegetation – i.e. plant photosynthetic productivity – around the planet.

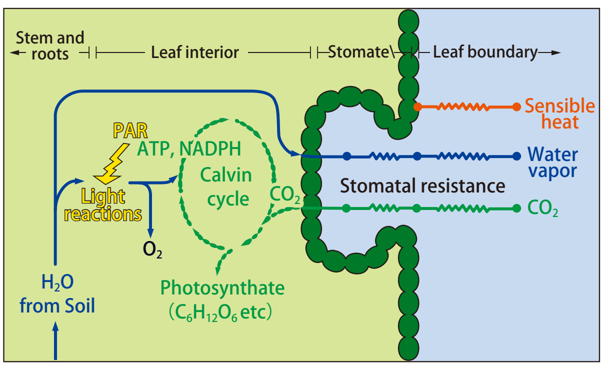
In addition, by collaborating with marine researchers and integrating their data from marine biospheres, he was able to create the first global CO_2 absorption and emission distribution map that included both terrestrial and marine ecosystems (see Fig.3 map).

Figure 1: Relationship between photosynthetic rate, leaf nitrogen content and light intensity



Based on Field (1983, *Oecologia*)

Figure 2: Leaf photosynthesis and stomatic function



Stomatal resistance measures how easily CO_2 and water vapor pass through the stomata of a leaf. By incorporating Field's formulas for photosynthesis, it became possible to estimate the flow of CO_2 and water vapor between plants and the atmosphere.

Based on Sellers *et al.* (1997, *Science*)

Artificial CO_2 emissions and CO_2 absorption in the environment

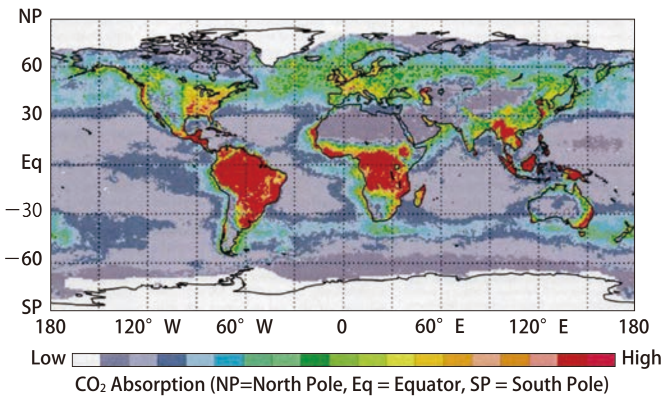
Field was also able to estimate how much artificially produced CO_2 would be absorbed by land and marine ecosystems, and how much would remain in the atmosphere (see chart in Fig. 4).

Artificial CO_2 emissions are rising every year, and the amount of CO_2 absorbed by oceans is rising accordingly, but Field discovered that CO_2 absorbed by terrestrial vegetation fluctuates wildly from year to year. It was thought that CO_2 was absorbed by land vegetation in a stable way, but that turned out not to be the case. His estimation showed that any CO_2 not absorbed on land remains in the atmosphere, and is thereby responsible for the rise of atmospheric CO_2 concentration.

Through his research, Field has been able to show how much CO_2 is absorbed by marine and terrestrial ecosystems as global warming continues unabated, and to show how many years it will take to reduce atmospheric CO_2 concentration if humanity is able to reduce its CO_2 emissions and limit deforestation and other related changes in land use and land cover.

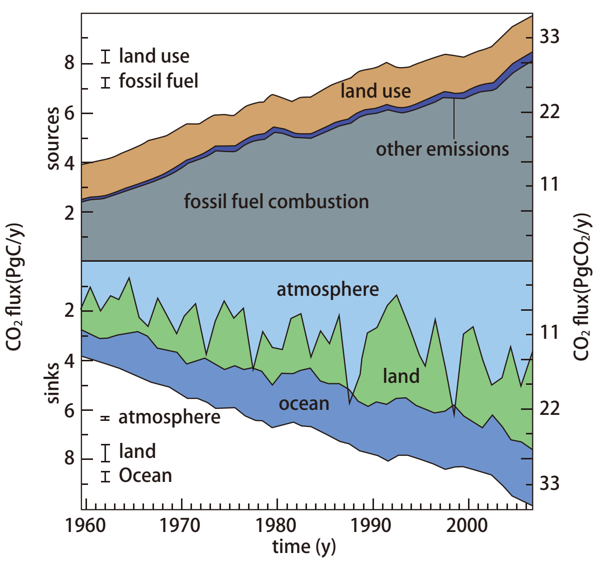
Field's research began with the observation of a single leaf and developed into a way to study global biospheric productivity using CO_2 emissions, contributing immensely to the study of climate change, and laying the scientific foundation for international discussions to implement the measures needed to combat global warming.

Figure 3: Distribution of CO_2 absorption in the global biosphere



Field *et al.* (1998, *Science*)

Figure 4: Artificial CO_2 emissions and environmental CO_2 absorption



Based on Canadell *et al*. (2007, *PNAS*)