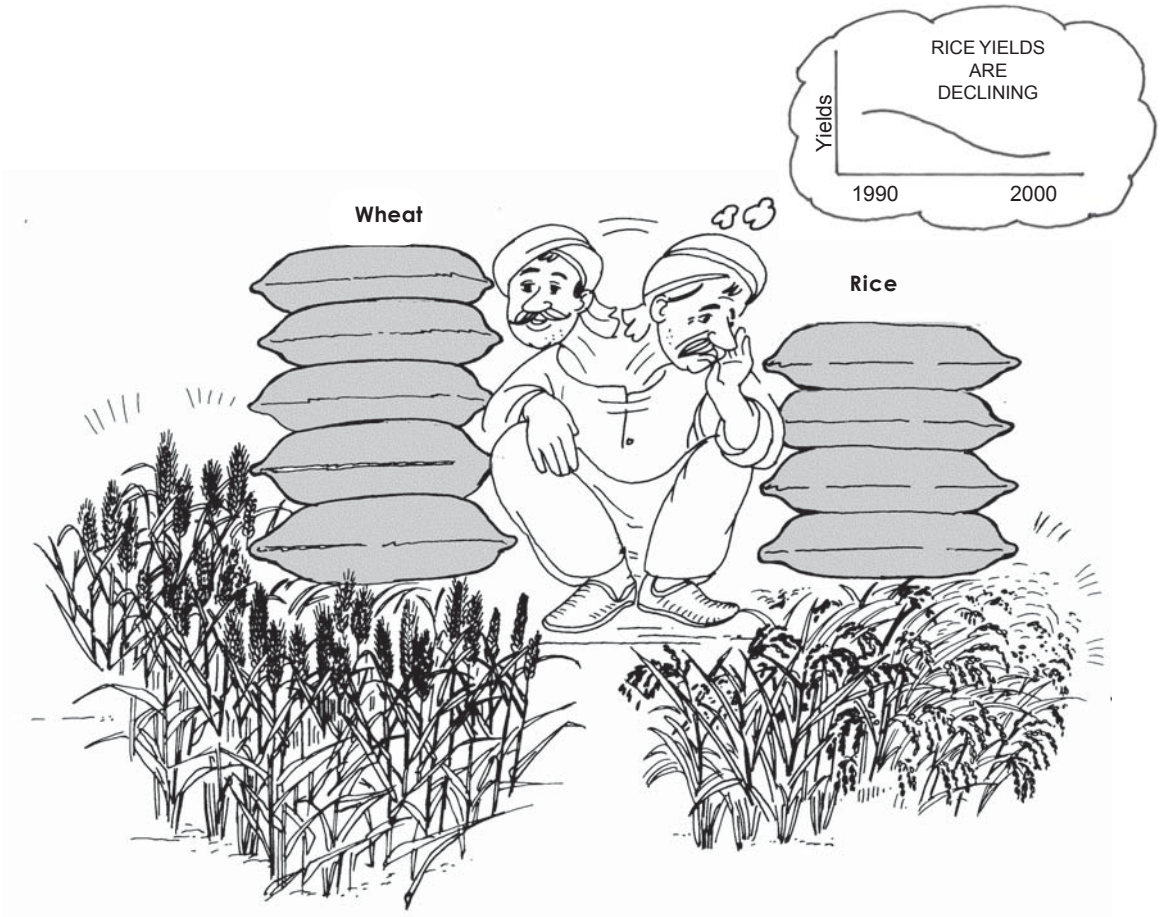
How Extensive are Yield Declines in Long-Term Rice-Wheat Experiments in Asia



Long-term experiments (LTEs) provide opportunities for monitoring long-term changes in crop yields and soil nutrient balances and identifying factors associated with such changes. They also provide data on which to base rational judgments about the bio-physical aspects of sustainability. Analysis of the yield trends of 33 LTEs at different sites has successfully investigated the extent and causes of yield declines of rice and wheat in South Asia and China.

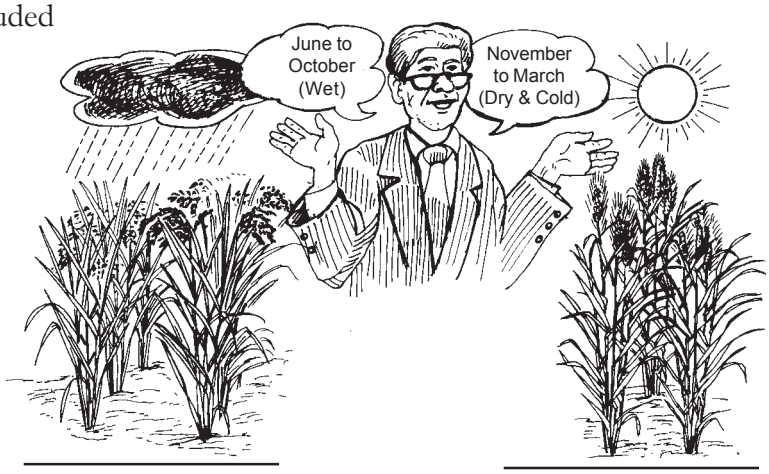
The LTE sites are located within subtropical to warm temperate climate. These areas have cool and dry winters, and warm and wet summers.

Soil fertility varies widely across these LTEs in terms of organic carbon (3 to 19 g/kg), Olsen P (0.005 to 0.26g/kg) and available K (0.036 to 0.225g/kg). Organic carbon content is generally higher in the soils of the lower IGP than in those of the upper IGP.

Crop Management in LTEs

Most of the experiments included **two crops per year:**

- Rice grown in the months of June to October under monsoon conditions.
- Wheat grown during cooler and comparatively dry winter months (November to March).



All the LTEs used semi-dwarf high-yielding cultivars of rice and wheat. During the experiments, the varieties were even changed in favor of the best available in the region.

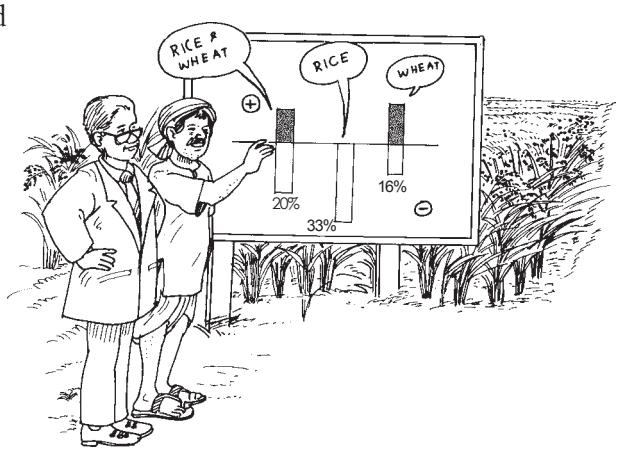
Trends in Rice and Wheat Yields

Rice-Wheat

Yields of wheat were more stable over time as they declined at only two sites and increased at four sites. However, yield trends in rice-wheat systems were mainly dominated by the trends in rice yields.

Wheat

Of the 33 LTEs, 16 showed negative yield trends. However, wheat yields were more stable than rice yields as is evident from the fact that only two LTEs showed significant declining trends as compared with eight LTEs in rice. Positive trends were observed in 17 LTEs, four of which were significant. It has been found that rice yields are less stable than wheat but the optimal conditions for rice lead to poor soil condition for growth of wheat. Thus, although wheat yields are stable, they probably are still lower than potential yields.



Rice

Region-wise averages were negative in all except one of the transects of the IGP, but no significant decline was observed at sites outside the IGP and in China.

It was interesting to note that the rice yields were similar in the IGP 2 and China but wheat yields were higher in the IGP 2 than in China. Sites in the non-IGP (excluding China) showed the lowest average system yield at 7t/ha.

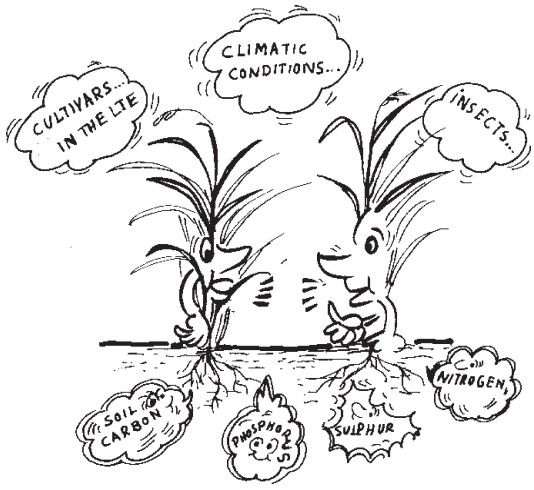
The analysis of yield trends of 33 LTEs in Bangladesh, China, India and Nepal suggest that though significant yield decline is not widespread, yields of both rice and wheat are **stagnating** in 72% and 82% of the LTE respectively. In other 22% and 6% of the LTE, the yields of rice and wheat respectively are **declining.**

Why Yields Decline?

Increases at some sites have been attributed mainly to improved varieties that were grown in place of the normally recommended varieties. Stagnation and reduction in yields may be because of negative changes in any of the following factors:

- soil organic matter and associated nutrient supply;
- exogenous supply of balanced nutrients;
- cultivars used in LTE;
- adverse or unsuitable climatic conditions;
- pressure of insects, diseases and weeds; and
- inadequate crop and soil management.

As all the experiments were conducted on research farms where crop and soil management and insect and disease control measures were done as per pre-determined schedule, these could not be the reason for stagnation and decline in yields. Likewise, rice and wheat varieties were constantly exchanged for cultivation of improved germplasm, a breakdown in crop genetic potential was not likely. Therefore, the remaining soil-related factors and gradual depletion of some nutrients, a downward shift in nutrient response function and changes in the climate may be the possible reasons for the declining yields.



Why yields decline?

Does Wheat Suffer After Rice?

Data indicate that in the rice-wheat system, rice yields, particularly in the IGP, have more disturbing trends than wheat yields. Scientists have given a hypothesis that this happens mainly due to puddling done in growing the rice crop. The soils in the rice-rice and rice-wheat systems differ vastly in texture. The rice-rice soils have much higher clay content with low bulk density compared with the alluvial soils which are sandy loam to silt loam with high bulk density. It is hypothesized that continuous puddling in light soils can cause soil compaction because of crystallized ferric oxides making the soils shallow. These shallow soils do not allow roots of the rice plant to penetrate in the soil resulting into lower yields.

Rice crop, as against wheat crop, suffer more because of this phenomena of soil compaction because rice is a shallow-rooted crop and mainly depends on 30 cm surface layer for all the nutrients. Naturally, in such a situation, rice crop suffers early due to nutrient deficiency as compared to wheat crop. In addition to its deeper root system, wheat is a longer duration crop and has 30-35 days more to mine soil nutrients.

Nutrient Depletion and Imbalance

There have been significant decreases in the rice-wheat yields when no fertilization was done. Yields of rice at various sites ranged from 1.6 to 5.8 t/ha because of varying fertility levels and other constraints. The mean yields of rice dropped from 2.8 to 1.6 t/ha, a 45% decrease. The mean wheat yields dropped from 1.2 to 0.9 t/ha, a 21% decrease.

Possible Causes of Decline in Rice and Wheat Yields in Various LTE

Causes	LTE
1. Decline in soil carbon	Ludhiana 1, Pantnagar 1 and Bhairahwa 2
2. Decline in soil N	Ludhiana 1, Pantnagar 1 and Bhairahwa 1
3. Decline in availability of P	Bhairahwa 1, Bhairahwa 2, Tarahara and Pantnagar 4
4. Decline in soil K	Ludhiana 1, Karnal 1, Pantnagar 4, Pusa, Bhairahwa 1, Bhairahwa 2 and Tarahara
5. Decline in available Zn	Pusa, Bhairahwa 1
6. Delay in planting	Bhairahwa 1 and Bhairahwa 2
7. Decrease in solar radiation	Ludhiana 1
8. Increase in minimum temperature	Ludhiana 1

Decline in Soil Carbon

Carbon, the soil conditioner, source of nutrients and substrate for microbes, appears to have declined in some of the LTEs. Total soil carbon declined due to continuous cultivation in Bhairahwa 1, Ludhiana 1, Pantnagar 1 and other LTEs in the IGP. Even when supplied with the recommended NPK, there was corresponding decline in yields of rice and wheat. In the major rice-wheat regions of northwest India, soil C has decreased from 0.05% in the 1960s to 0.02% in the late 1990s. Such a decline is prevalent throughout rice-wheat systems in India.

However, scientists have found a positive role for organic matter along with NPK.

Does Soil Organic Matter Increase Yields?

Scientists say, soil organic matter (SOM) does not necessarily maintain or increase yield. For instance, SOM content was increased in the rice-wheat in Tarahara, LTE but yields declined in both the crops. In Bhairahwa LTE, continuous application of FYM did increase the SOM but not yields. The data suggest that SOM and crop productivity are not linked. Perhaps total size of SOM is not as important as the size of the active fraction involved in nutrient cycling. While high SOM is critical in attaining yields close to potential yields, other factors should also be optimal.

In Bhairahwa 1 LTE, where SOM increased but yield declined, it was found that gradual depletion of soil K and its insufficient application caused the yield decline. Therefore, there is a need to understand and quantify the role of SOM in relation to crop productivity and sustainability.

Depletion of Soil Nitrogen

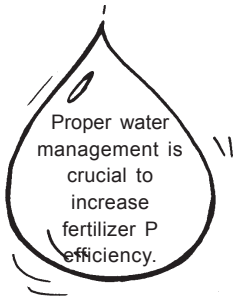
Three possible reasons have been identified for yield decline in rice-wheat systems:

- soil nitrogen supply;
- nitrogen uptake efficiency; and
- fertilizer N-use efficiency because of biotic or abiotic constraints.

To achieve higher yields in rice-wheat systems, time of N application is important. This is more important in sandy rice-wheat soils having high pH. Such soils are common in the IGP areas where nitrogen losses by leaching and volatization are high.

Reduced Soil P Availability

Total P was not a limiting factor in influencing yields of rice-wheat systems. However, unfavorable soil conditions can reduce its bio-availability contributing to decline in yields.



The differential availability of P for rice and wheat could be due to the following:

- Changes in the oxidation-reduction status of soil resulting from continuous submergence in late rice.
- Intermittent wetting and drying in early rice and aerobic conditions during wheat cultivation.
- Reduced soil conditions because of reduction of ferric iron phosphate compounds and increased solubility of Ca-P compounds. This happens mainly in alkaline soils due to decreased pH. Use of gypsum to ameliorate sodic soils reduces P availability as calcium phosphate species are formed.
- Increased absorption during the drying phase and differences in soil P diffusion in submergence and dry soils.

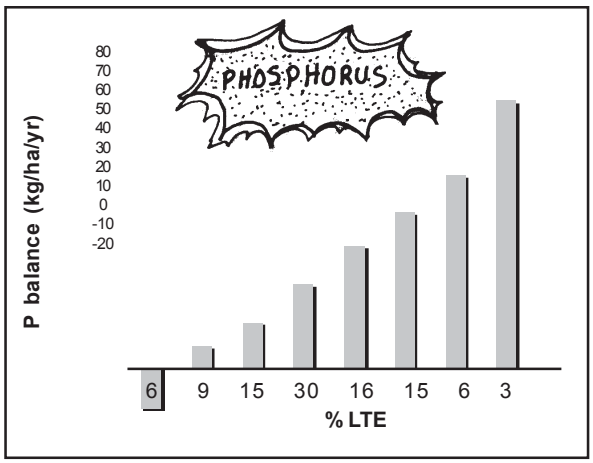
Depletion of Soil K

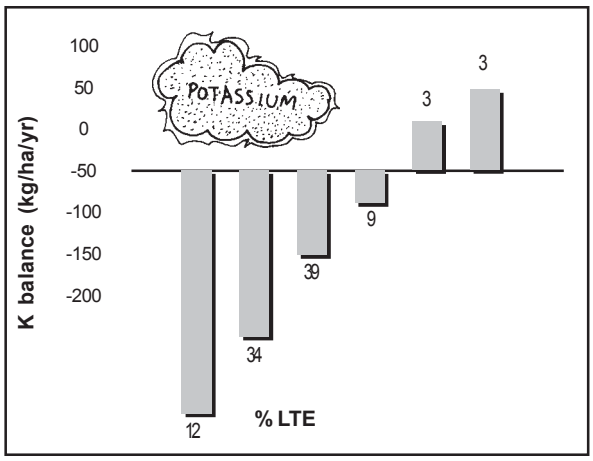
All the LTEs with a significant yield decline had large negative K balance. However, P balance was positive in most LTEs. In 90% of the LTEs, the fertilizer K rates used were not sufficient to sustain a neutral K input-output balance.

The following suggestions have been made to keep the K balance in the soils:

- Higher doses of K application are needed to increase the yield levels of both rice and wheat.
- Incorporate straw into the soil to replenish K to some extent. Identify other sources of animal feed than straw.

Potash deficiency reduces the yields in rice and wheat even in most of the soils of the alluvial flood plains of Asia which are normally considered to be rich in K. It may also be a misplaced perception that irrigation water supplies enough K to the crops.

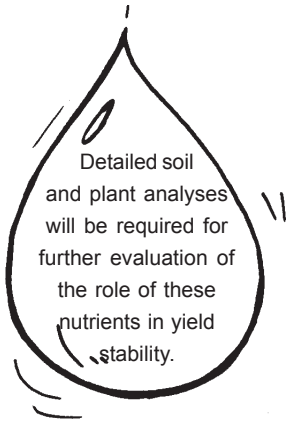




Depletion of Micronutrients

Micronutrient deficiency exists in the IGP, especially in the calcareous soils. More stable yields were obtained with farmyard manure (FYM) treatment as against NPK treatment.

As for other micronutrients, the deficiency was not widespread. Soils are not normally deficient in S because application of single superphosphate supplies the needed levels of this nutrient. For meeting the requirements of other micronutrients, blanket application once in three years should be done or in case deficiency symptoms appear.

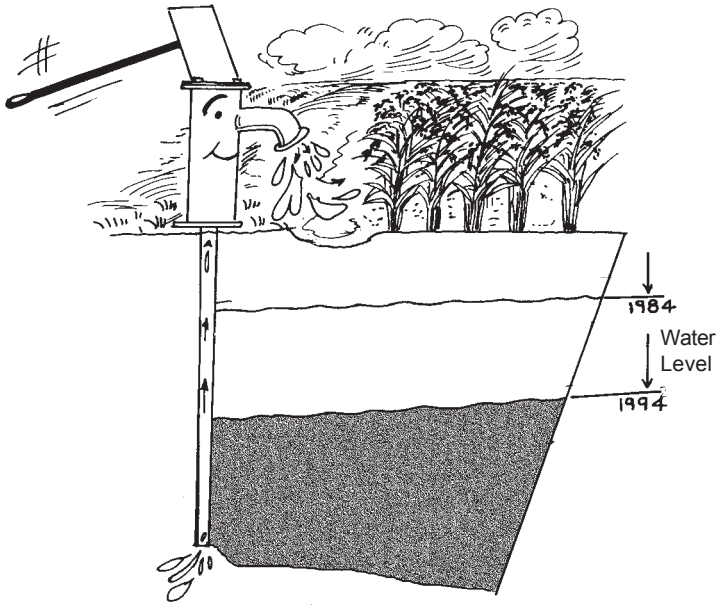


Soil Salinity and Depleting Groundwater

Soil salinity is perceived as a cause of declining yields in farmers' fields in the rice-wheat system of the IGP, particularly in Transects 1 and 2. Frequent irrigations in these highly porous and light-to medium-textured soils cause salinity.

Groundwater Decline

In Haryana, India, the rice-wheat growing areas in the districts of Ambala, Kaithal, Karnal, Kuruhkshetra, Panipat and Yamunanagar, show a considerable groundwater decline. In Punjab, India, a 2-5 m decline in the water table has been recorded from 1984 to 1994.



Delay in Crop Planting

Another cause of yield decline, especially for wheat, is delay in sowing. It results to decrease in yield because of rise in temperature at grain filling stage. This yield loss was noticed in Bhairahwa 1 because of delay in sowing. Sowing wheat after 15-20 November resulted in decrease of yield by 1% every day! Late planting not only reduces yield but also reduces efficiency of inputs applied to the wheat crop.

Reasons for Late Planting of Wheat in Rice-Wheat System

- Late planting of preceding rice crop.
- Growing long-duration, photo-sensitive, high quality basmati rice that matures late.
- Long turn-around time between rice harvest and wheat planting is required.
- Growing of a short-duration crop planted after rice

Summary

Yield stagnation has set in the rice-wheat system in all the LTEs and decline in some LTEs, particularly in rice. It is difficult to attribute any single reason for this decline. The reasons may be more location-specific. Depletion in soil nutrients, reduced availability of P, delay in planting, decrease in solar radiation and higher temperatures may be the causes of the decline in some locations. Depletion of soil K seems to be a general cause.

The main bottleneck in the identification of specific reasons for declining yield trends can only be identified if historical soil and plant samples are available for analysis. Therefore, more detailed data collection and archives of soil and plant samples should be determined to find out this cause-and-effect relationship.

- Greater stability in wheat yields does not mean conditions are favorable for wheat. Yields are still below potential.
- Assessment of pest and disease pressures and interactions with nutrient management is essential.
- Greater attention should be given to the role of organic matter in rice-wheat system.
- New experiments to assess long-term effects of zero-tillage and reduced tillage practices are required to probe further to this phenomenon.
- Accurate assessment of nutrient budgets is required. Non-nutritional benefits of some of the nutrients need further study.
- More experiments with residue management are needed.

Adapted from:

Ladha, J.K., D. Dawe, H. Pathak, A.T. Padre, R.L. Yadav, B. Singh, Yadvinder Singh, Y. Singh, P. Singh, A.L. Kundu, R. Sakal, N. Ram, A.P. Regmi, S.K. Gami, A.L. Bhandari, R. Amin, C.R. Yadav, E.M. Bhattarai, S. Das, H.P. Aggarwal, R.K. Gupta and P.R. Hobbs. 2003. How Extensive are Yield Declines in Long-term Rice-Wheat Experiments in Asia? Journal of Field Crops Research. Article in press. Available at: http://www.sciencedirect.com.

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