"If you desire peace, cultivate justice, but at the same time cultivate the fields to produce more bread; otherwise there will be no peace."

"The first essential component of social justice is adequate food for all mankind. Food is the moral right of all who are born into this world."

Dr. Norman E. Borlaug (1914-2009)

Borlaug Institute for South Asia

CIMMYT

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Borlaug Institute for South Asia

In 1963, wheat scientist and humanitarian Dr. Norman E. Borlaug joined with visionary scientists, policymakers, and farmers in India to create a movement—a revolution that took the region from famine in 1965-1966 when India imported 10 million tons of grain, to food self-sufficiency. However, in 1969, Dr. Borlaug correctly predicted that this Green Revolution boost in food production would only last 20-30 years, and warned that these achievements were a reprieve, buying time for humanity to adopt more responsible policies to manage population growth and use of natural resources. The last two years of his life saw his warning become painfully true with the food crisis in 2008 and the population of the hungry surpassing 1 billion in 2009. Dr. Borlaug passed away in September 2009, leaving his legacy, his spirit, and an enjoinder to push forward with a new Green Revolution to "take it to the farmer."

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The Borlaug Institute for South Asia: Catalysing a new Green Revolution

Proposal for a new India-based, CIMMYT agricultural research and development institute to boost the productivity of maize and wheat cropping systems in South Asia

Food insecurity, natural resource scarcity, and climate change in South Asia

As foreseen by late Nobel Peace Laureate, Dr. Norman E. Borlaug, the effects of the Green Revolution that he and other visionaries created in the 1960s-70s are quickly waning in South Asia, a region that is home to half the world's poor. Annual yield growth rates for wheat and other cereals have fallen well below population growth rates so food prices are rising, hurting poor consumers and economic growth.

With a population reaching 1.3 billion by 2020, *India embodies future food security concerns*. Best projections forecast that by 2020—only 10 years from now—the demand for wheat and maize, major staple foods in South Asia, will be 124 Mt and 30 Mt, respectively. India alone is expected to require around 93 Mt/year of wheat. Production has not kept pace with increasing demand. Productivity growth has flattened for almost a decade and attainable yields are increasingly constrained by the challenges of climate change, including rising temperatures; land, water and fertilizer scarcity; aquifer depletion; soil degradation; and diseases, insects, and weeds.

Losses in the wheat crop from rising temperatures because of climate change are projected at around 32 Mt per year, equivalent to USD 7 billion at current prices, leading India and the South Asian region to become net importers of as much as 50 Mt of food grain per year by 2030. Even maize, with a production growth of 4.2% per annum, is likely to experience falling yields because of climate change effects. By 2050, climate change may reduce production by 6-23% for maize and 40-45% for wheat. Fortunately technological breakthroughs for a new Green Revolution—drought and heat tolerance, water and nitrogen use efficiency, insect and disease resistance, marker assisted selection, allele mining, precision and conservation agriculture, transgenics, and information technology—offer the means to overcome these challenges.

Agricultural technologies developed with and for India will have relevance throughout South Asia. India's diverse ecologies and cropping systems include the prevalent systems found in most other South Asian countries. The relative geographic, social, economic, and agricultural integration of South Asia, along with the impressive research capacities in India and shared ecological and poverty concerns, supports the logic of locating an international **Borlaug Institute for South Asia** in India.

Building on the Borlaug legacy to create a new Green Revolution

The Borlaug Institute will catalyse a second Green Revolution in India and South Asia, in particular within the countries of the South Asian Association for Regional Cooperation (SAARC), and contributing to food security and sustainable productivity growth *in both irrigated and rainfed production areas* by adapting wheat and maize systems to the emerging challenges of climate change, natural resource scarcity, and market demands. More specifically the Institute will develop and promote:

- Highly-productive and resilient hybrid maize and wheat varieties equipped for the challenges ahead.
- Precise new agronomic practices that require fewer inputs and improve the soil.

- Decision-support and marketing systems to integrate R&D with value streams.
- Capacity building approaches and skills, to efficiently develop, disseminate, and manage technologies, products, and other intellectual property.

Why CIMMYT?

- The International Maize and Wheat Improvement Centre (CIMMYT) of the CGIAR is the recognized leader in global maize and wheat R&D networks, with linkages to public agricultural research programs, private companies, advanced research institutes, NGOs, and farmer associations worldwide, giving it privileged access to germplasm, practical knowledge, and advanced science that can be adapted and channeled through the Borlaug Institute to benefit India and South Asia.
- CIMMYT has been associated with India for more than four decades, starting with the introduction of the high-yielding semi-dwarf wheat varieties that launched the Green Revolution and helped Indian wheat production increase from 11 Mt in 1967 to more than 80 Mt in 2009.
- Through the Rice-Wheat Consortium for the Indo-Gangetic Plains, CIMMYT helped promote and test the use of zero-tillage to sow wheat after rice, a resource-conserving practice now used on 1.8 million hectares in South Asia.

Logistics and principles

The Borlaug Institute will operate as an international organization managed by CIMMYT. It will require land, facilities, and basic annual core funding from the Government of India. The requested start-up investment is Rs 150 crore (USD 32 million), plus Rs 35 crore (USD 7.5 million) of annual core funding for operations. Project funding from international donors is expected to more than double the Institute's annual operational budget. Collaboration with the Indian Council for Agricultural Research (ICAR) will be intensified and defined through five-year "Workplans for Scientific and Technical Partnership on Maize and Wheat Systems". Governance of the Borlaug Institute will be the responsibility of the CIMMYT Board of Trustees, who in consultation with leaders / representatives of South Asian stakeholders will set the Institute's agenda. The Institute will interact with members of collaborative research projects through joint planning, execution, and review of projects to implement its agenda. In the organization and management of the Borlaug Institute, CIMMYT will adhere to the following basic principles:

- Visionary research and demand-driven product delivery in service to the poorest communities in South Asia.
- Enhanced food security in view of increasing climate change, resource scarcity and demands for quality.
- Regional and international cooperation among research and development institutions, non-governmental organizations, and the private sector.
- Free exchange of information, technologies, germplasm, and scientists.
- Human resource development through the chain from research to the marketing of cutting-edge products and technologies, and impact assessment.
- Application of international performance standards for research, management, biosafety and training.

1. Introduction

Challenge for the world

Based on the report by the FAO on *"How to Feed the World in 2050"*[1], the world's population will reach 9.1 billion in 2050, 34% more than today. Nearly all of this population increase will occur in developing countries. In order to feed this larger, more urban and richer population, staple crop production must increase 70% to accommodate the demands for food, feed, biofuel, and industrial products. In developing countries, 80% of the necessary production increases must come from increases in yields and cropping intensity, and only 20% from expansion of arable land. Despite this growing demand, the global rate of growth in yields of the major cereal crops has steadily declined in recent years, from 3.2% per year in 1960 to 1.5% in 2000.

The world food situation is further challenged because crop production must increase in coming decades even as land, irrigation water, fertilizer, fuel, and agricultural labour become scarcer or more costly and climate change impacts intensify. Unless countries invest in increasing agricultural productivity and enhancing market performance, food prices will escalate, driving people who recently became food-secure back into poverty and causing social unrest among both rural and urban poor.

Challenge for South Asia

With 1.6 billion inhabitants, South Asia is home to half of the world's poor; 75% living in rural areas. The rapid increase in food grain productivity from the Green Revolution in the 1960s-70s improved food security and cut rural poverty, but its effects are quickly waning. In recent years, annual yield growth rates for the two main food staples have fallen well below what is required to keep abreast of a burgeoning population. Food prices are rising, to the detriment of poor consumers and economic growth. Technology adaptation and adoption have been slow and attainable yields have been constrained by land and water scarcity and aquifer depletion, the high price and scarcity of fertilizer, soil degradation, rising temperatures from climate change, and the impacts of diseases, pests, and weeds.

South Asia will be hit particularly hard by climate change effects, and yields of irrigated crops will decline sharply. By 2050, these effects may reduce production by 6-23% for maize and 40-45% for wheat[2]. The impact of climate change in irrigated areas cannot be overcome by increased pumping, because unsustainable extraction of water for agriculture is quickly draining aquifers[3]. Demand increases on the other hand require an average annual yield growth of 1.5% for wheat and 3.5% for maize by 2020, if no additional land is brought into cultivation. And with its high population density, South Asia has essentially reached the limits of "extensive" cultivation: per capita cropland has dropped 40% since 1961 and is now only 0.27 ha[4]. Future production growth must therefore come from making cereal systems more productive, profitable, sustainable, and resilient.

1. FAO High-Level Expert Forum, Rome, Italy, 12-13 October 2009.
2. Asian Development Bank and IFPRI 2009. Building climate resilience in the agriculture sector in Asia and the Pacific. Mandaluyong City, Philippines: Asian Development Bank, 2009.
3. UNDP, 2006.
4. FAO, 2009.

Challenge for India

India's population is expected to increase from the present 1.175 billion in 2010 to 1.331 billion in 2020. Agriculture is the dominant economic sector and provides livelihoods to about 70% of the population and employment for about 60% of the labour force. The 2001 census showed 28% of the Indian population residing in cities, a proportion expected to approach 40% by 2020[5]. Higher personal incomes and increased urbanization tend to raise per capita food consumption and the use of meat and dairy products, the latter requiring increased forage and feed grain production.

India will be among the countries most adversely affected by climate change (Figure 1), with losses of 30-40% in agricultural productivity due to the severity of changes in rainfall patterns and events, snow pack, and higher temperatures and extremes. The Inter-Governmental Panel on Climate Change (IPCC) and the India Meteorological Department predict that India's mean temperatures will rise by 2-4°C by 2050 and this will be associated with a doubling of the number of 'heat shock' days (>30°C). As a result, irrigation demands to sustain future production levels will sharply increase, even though aquifers in many areas already record a net loss of water[6]. Losses in the

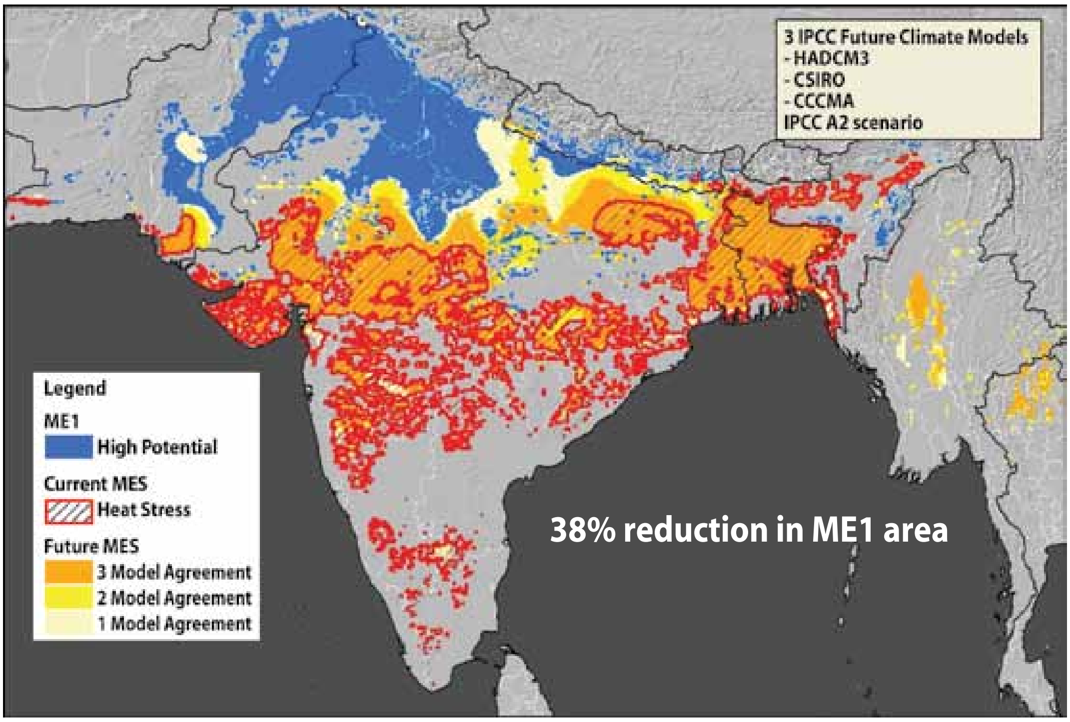

Figure 1. Climate change will cause a 38% reduction in favourable wheat cropping areas in South Asia by 2020. Another CIMMYT study[7] predicts a 51% decrease in the most favourable wheat cropping areas by 2050 due to heat stress.

5. Report of the Committee on India Vision 2020, Planning Commission, Government of India, New Delhi, December, 2002.
6. Rodell M., I. Velicogna and J.S. Famiglietti. 2009. Satellite-based estimates of groundwater depletion in India. Nature 460, 999-1002.
7. Ortiz, R, KD Sayre, B Govaerts, R Gupta, GV Subbarao, T Ban, D Hodson, JM Dixon, JI Ortiz-Monasterio, and M Reynolds. 2008. Climate change: can wheat beat the heat? Agriculture, Ecosystems and Environment 126 (1-2) 46-58.

wheat crop alone may reach 32 Mt per year, equivalent to USD 7 billion at current prices. These problems will be exacerbated by soil degradation, rising fertilizer prices, and competition for quality land and water from non-agricultural sectors.

Future food security: A new Green Revolution

The compounding effects of increasing demands, climate change, and resource scarcity pose unprecedented challenges to India and South Asia. Research to adapt Indian and South Asian agriculture to these changes must be accelerated and the best available science and technologies deployed to sustain food security and assure continued economic development.

In his Speech to the Nation on Independence Day, August 15, 2009, the Prime Minister of India Dr. Manmohan Singh stated: *"We will have to adopt modern means to be successful in agriculture. We will have to make more efficient use of our scarce land and water resources. Our scientists must devise new techniques to increase the productivity of our small and marginal farmers. More attention will have to be paid to the needs of those farmers who do not have means for irrigation. The country needs another Green Revolution and we will try our best to make it possible."*

This new Green Revolution must produce food with much greater efficiency under increasingly adverse conditions. Petroleum and phosphate production will peak globally by mid-century, and water and land resources are already declining in South Asia. Fortunately technological breakthroughs—drought and heat tolerance, water and nitrogen use efficiency, insect and disease resistance, marker assisted selection, allele mining, precision and conservation agriculture, transgenics, and information technology—offer the means to achieve this Revolution. India must aggressively acquire and adapt new technologies and institutional innovations that can boost past achievements and help create a new Green Revolution both in irrigated settings and in rainfed areas that were bypassed in the past. Indian scientists must be able to access wider genetic variation and the newest plant breeding and crop management science and know-how in order to rise to the challenges outlined by Prime Minister Manmohan Singh. They must provide farmers with more productive varieties and sustainable crop and natural resource management options that will be able to feed the nation today and in the future.

2. Can the Borlaug Institute be part of the solution?

History and the role of CIMMYT

The International Maize and Wheat Improvement Centre (CIMMYT) has been associated with India for the past 46 years, starting when Dr. Norman Borlaug was invited to work with the Indian Agricultural Research Institute, New Delhi, in 1963. By introducing high-yielding, semi-dwarf wheat varieties, Dr. Borlaug, along with policy makers, scientists, and farmers, initiated the Green Revolution in South Asia and contributed to the transformation of Indian wheat production. The Green Revolution legacy of expanded cereal production in Asian countries "bought 20-30 years of time," according to Dr. Borlaug.

Combining the world's largest collections of wheat and maize genetic resources with next-generation genotyping technologies, CIMMYT can provide access to previously untapped genetic variation for traits that confer tolerance or resistance to environmental and biological stresses, that increase water and nutrient use efficiency, and that improve grain quality. Through its unique mandate and position, CIMMYT is able to access and use advanced germplasm and state-of-the-art technologies and know-how—including those typically available only within the multinational private sector—and make these available to national public sector programs and smaller companies. The Borlaug Institute will enable Indian and other South Asian scientists to work more closely with CIMMYT's pioneering programs on abiotic-stress tolerance, next-generation marker assisted selection, allele mining, wheat yield potential, disease resistance, nutrient and water-use efficiency, conservation and precision agriculture, and newest initiates to address the region's daunting challenges to crop production.

Wheat and maize and food security in South Asia and India

South Asia

Wheat and maize are major staple food crops and vital for food security. Wheat area in South Asia surpasses 37 M ha, which constitutes roughly 16% of the world's wheat area and 15% of its production[8]. Wheat production in South Asia was 101 Mt in 2007 and demand by 2020 will approach 124 Mt. Maize production in South Asia was 25 Mt in 2007 and is expected to reach 30 Mt by 2020.

Wheat in India. Overall production of wheat in India has risen from 11 Mt in 1967 to a record 80.6 Mt in 2009[9]. The projected national wheat production requirement for 2020 is around 94 Mt per year—14 Mt more than farmers now produce. The overriding concern is that wheat productivity growth has flattened for almost a decade, irrigation water has become more scarce and costly, and future wheat productivity increases are greatly threatened by rising temperatures, aquifer depletion, reduced snow pack, soil degradation, and decreasing investments in large-scale irrigation development.

8. FAO, 2007. FAOSTAT database, FAO, Rome.
9. Singh, S.S. (2009). Wheat Production and Climate Change Study – Background Paper. Directorate of Wheat Research, Karnal, India.

Maize in India. Maize is cultivated in diverse agro-ecologies year-round on nearly 8 M ha in India, and in 2008-2009 contributed 19.3 Mt[10] of grain to the national food basket. Maize grain is used as food, poultry/animal feed, and for myriad industrial uses. In the last decade, maize production has grown at 4.2% per annum—faster than for any other cereal grain—and maize stands to become the new Green Revolution crop. It is less affected by heat than rice and wheat and therefore replaces these crops as temperatures rise, irrigation water becomes scarce, and the demand of a wealthier population for animal products increases. Over 80% of the maize crop is grown under rainfed conditions where droughts, flooding, soil degradation, pests, and disease depress yields. Maize yields currently average just under 2.5 t/ha, but must continue to rise at 3.5%/year if the estimated demand of 30 Mt in 2020 is to be met.

Addressing potential deficits

India needs to produce additional maize and wheat by 2020 to sustain its national food security. Since opportunities for further expansion in the areas of these crops are quite limited, productivity enhancement and croping intensification are the only routes available to India and other SAARC countries to remain self-sufficient for food. *"The world has the resources and technology to eradicate hunger and ensure long-term food security for all, in spite of many challenges and risks. It needs to mobilize political will and build the necessary institutions to ensure that key decisions on investment and policies to eradicate hunger are taken and implemented effectively. The time to act is now"* (Executive Summary, How to Feed the World in 2050[1]).

10. Press Release, Press Information Bureau, GOI, July 2009.

3. What can the Borlaug Institute offer?

Vision

The Borlaug Institute for South Asia will:

- Help to catalyse a second Green Revolution in India and South Asia for food security and sustainable productivity growth in both irrigated and rain-fed production areas.
- Adapt wheat and maize systems to the emerging challenges of climate change and natural resource scarcity and degradation, and quality preferences for the near future and also to 2050 and beyond as these challenges intensify.
- Become an international institute of excellence for maize and wheat in South Asia, training a future generation of internationally connected and experienced scientists.

Objectives

The Borlaug Institute will:

- Create state-of-art research facilities to work with and support the maize and wheat research and development community in India and South Asia.
- In collaboration with local scientists, address challenges of regional importance, including accelerating demands for maize and wheat, climate change, water shortages, soil degradation, labour scarcity, and grain quality.
- Broaden the maize and wheat germplasm base available to scientists in India and South Asia by introducing, testing, adapting, and making available a greater diversity of germplasm as elite lines to public and private breeding programs.
- Strengthen local breeding programs with adapted lines that carry unique native and/or genetically modified maize and wheat traits to help meet future food-production challenges. These lines will feature higher yield potential and include sources of heat, drought, and waterlogging tolerance; resistance to emerging pests and diseases; and nutritional and specialty traits as demanded by the food industry.
- Utilize cutting-edge biotechnology and bioinformatics tools and methods and provide training opportunities for national partners and students to increase their capacity to routinely apply these tools.
- Provide a stable, long-term platform for holistic field experimentation on sustainable production systems, utilizing conservation and precision agriculture technologies and GIS-RS information that address the biophysical and socioeconomic challenges encountered by farmers in South Asia. The platforms will also be used for training a new cadre of agronomists and extension agents with expertise in state-of-the-art technologies and methodologies.
- Develop decision support systems that integrate scientific knowledge, environmental data, economics, and management objectives to ensure that appropriate technologies and management approaches are developed for different growing environments and farmers.
- Serve as an incubator and platform for cross-disciplinary, cross-institutional, and cross-national collaboration, particularly with other research centres, the private sector, NGOs, and farmers, to rapidly adapt and disseminate new varieties, technologies and approaches.

- Facilitate the development, flow, regulatory approval, deployment, and stewardship of transgenic and other patented technology to address climate change and other challenges to food security.

How will this benefit India and South Asia?

- The Institution's global germplasm, technologies, and know-how will be promoted to diverse public, private, and non-governmental institutions involved in agricultural R&D and marketing in India and South Asia.
- Locally-adapted maize and wheat varieties and hybrids will be created that boost productivity despite increasing climate change, especially higher temperatures, drought and water-logging, disease and pest incidence, and resource scarcity.
- Farmers will gain access to new and locally-tested conservation/precision agriculture approaches to increase wheat and maize productivity, reduce soil degradation and inefficient use of natural resources, and mitigate effects of climate change.
- Public and private sector scientists and students from the region will enjoy access to an integrated R&D system that applies and offers globally-connected knowledge, diverse IP, high-quality facilities, and specialized services.
- A new cadre of scientists will become more confident and effective in developing and disseminating new technologies and varieties to South Asian farmers through public-private partnerships and regulatory agencies.
- Local industry will be strengthened through collaborative projects, access to Institute-created and/or -facilitated intellectual property, and mentoring programs.
- International collaboration opportunities, recognition, and influence for India resulting from the creation and operation of an India-based institute of excellence.
- Enhanced interconnections between South Asian wheat and maize research and commercial interests.

Why invest in an international, India-based institute?

Many of India's food security challenges are shared by its neighbours. Food security is a key component for political stability and peace with and amongst the nations of South Asia. Considering today's challenges, confining research for food security improvement to national borders is neither feasible nor prudent, as peace is a prerequisite for growth and development. The Borlaug Institute will enable India to strengthen its international commitment and visibility as a stabilizing regional force that works towards regional food security, peace, and development.

Furthermore, production systems in India are similar to those of other South Asian countries; germplasm, technologies, and know-how developed and shared by the Institute in India will be relevant and flow to surrounding countries. The Borlaug Institute will pursue and promote the global exchange of knowledge and research and offer India direct participation in emerging, international initiatives undertaken by CIMMYT.

4. Main activities of the Borlaug Institute

Wheat germplasm

The focus for wheat germplasm improvement will be to increase yield potential, water use efficiency, and heat tolerance in disease resistant lines and hybrids, while meeting the quality requirements of end-users and the processing industry. Heat tolerance and hybrid wheat systems require extensive R&D investment and the Borlaug Institute will become a centre of excellence for these research areas. Attention will also focus on diverse crop rotations, which require germplasm of varied growing cycle length and flowering and harvest time, and with enhanced seedling vigour and lodging resistance. Major outputs will include:

- Elite and parental lines, segregating populations, genetic stocks (synthetics, translocations, landraces) with enhanced yield potential and water use efficiency, better heat tolerance, disease resistance, and adequate end-use characteristics.
- Elite, more diverse wheat lines distributed and the performance results from regional nurseries analysed and shared with partners.
- Germplasm with up to 50% higher yield potential developed in the Wheat Yield Potential Consortium, verified in precision field trials in India, and made available to Indian scientists for local adaptation. This long-term project builds on several relatively simple approaches to enhancing photosynthesis efficiency of wheat.
- Hybrid wheats developed with 25% higher yield than currently grown cultivars under irrigated conditions and 30% over currently grown cultivars under severe heat stress.
- Cultivars with durable resistance for all major diseases (stem rust, leaf rust, yellow rust, spot blotch and septoria) released and grown in farmers' fields.
- Expanded collaboration with CIMMYT-Kenya and Mexico-based programs to identify and develop advanced lines that carry resistance to the Ug99 race of stem rust.
- Shuttle breeding with two full breeding cycles per year in India.

Maize germplasm

The demands for adapted germplasm in the various ecosystems of India—which are similar to those in neighbouring countries—require a targeted and system-specific approach to germplasm development. The Borlaug Institute will serve as the main Asian hub for the development, evaluation, and distribution of elite CIMMYT breeding lines in South and Southeast Asia and focus on:

- Increasing the water use efficiency and drought tolerance of maize grown under water scarcity or drought affected conditions.
- Building tolerance to excess moisture and flooding and resistance to biotic stresses into maize hybrids for northeastern India.
- Developing more cold tolerant maize inbreds for Rabi season maize production by introgressing temperate germplasm.
- Building heat tolerance into hybrids exposed to temperatures above 35°C.
- Providing new and stable sources of resistance where maize is affected by pests and diseases, including banded leaf and sheath blight, downy mildew, post-flowering stalk rots, and insect pests.

- Introducing and improving nutritionally enhanced or specialty corn types, including quality protein maize (QPM), sweet corn, baby corn, and pop corn.
- Ensuring that elite, stress-tolerant public maize germplasm remains easily accessible to small maize seed companies, allowing them to offer quality seed at affordable prices to smallholder farmers.

Modern breeding approaches

The Institute will assist public and private breeding programs in India and South Asia to use modern biotechnology and bioinformatics tools to accelerate progress in their own breeding programs. The approaches will include:

- Introduction and local identification and use of robust markers for disease resistance and quality traits.
- Marker assisted selection and genome-wide screens to speed breeding progress for complex traits.
- Allele mining using native collections to uncover rare and productive variations targeted for South Asia.
- Implementing protocols to screen and improve maize and wheat for tolerance to abiotic stresses (drought, heat, cold, water-logging) and important pests and diseases, including post-harvest pests and mycotoxins.
- Use of shuttle breeding between different locations in India and with CIMMYT international sites.
- Developing the capacity to use double-haploids, precision phenotyping, genotyping, and effective data analysis.
- Establishing biosafety facilities to test and introduce transgenes into locally-adapted maize and wheat, along with testing of high-priority traits.
- Integration of molecular data, phenotypic data, and pedigree information, which will be made available through the internet and as a decision making platform for regional breeding programs.
- Assistance and guidance in managing and using intellectual property.

Conservation agriculture and precision-based production practices

To meet increasing food demands in South Asia, cropping system productivity must be intensified with sustainable management practices that do not degrade or deplete natural resources. This requirement poses a massive challenge that will only be met by making certain that cropping systems research for development is technologically innovative, scientifically rigorous, cognizant of emerging issues like climate change and relevant to the needs of South Asian farmers. Such ecological intensification of agriculture is also increasingly knowledge intensive. Hence, the Borlaug Institute will develop tools and management approaches that enable the seamless integration of soil, weather, management, and market information into robust but simple decision-support products for farmers and service providers.

Much of South Asia suffers from varying levels and types of degraded land;[11] covering nearly 2/3 of India's total area (Sehgal and Abrol 1994 [12]). These lands escalate production and rehabilitation costs and reduce farm incomes/livelihoods, causing regional inequities and reduced ecosystem services. Resource poor farmers practicing rainfed agriculture on these lands have limited ability to adapt and will be the first to feel the effects of unmitigated climate change. Negative impacts of climate change will feed the degenerating spiral driven by land degradation's biophysical and socioeconomic effects.

Highly productive, sustainable land management requires the maintenance of a protective surface cover (living plants or mulches) and adequate levels of soil organic matter and organisms to allow gas, water, and nutrient exchanges with plants. Based on conservation agriculture principles, sustainable land management will raise agricultural productivity, enhance the quality of the environment and natural resources, and increase biodiversity. Meanwhile precision agriculture techniques will be developed and applied to further boost productivity by using fewer inputs more effectively.

To develop, test and promote effective and profitable conservation/precision technologies and varieties for farmers, the Borlaug Institute will establish 14 satellite locations. For the selection of these locations and to efficiently target and upscale technologies for rainfed and irrigated cropping systems, the many relevant bio-climate, soilscape, and poverty meta-databases of the region will be integrated through mixed-effect models in a geo-referenced framework to delineate similarity zones. R&D at these locations will be supported by the Institute's geographic information system (GIS) and reflectance spectroscopy (RS) information lab for land diagnosis and assessment, in-season yield/production forecasts, fertilizer advisories, and policy decisions on fertilizer and technology support allocations.

The Institute and network of 14 satellite research locations for major maize- and wheat-based farming systems in South Asia will be used as platforms to:

- Link the research community with all facets of the agricultural innovation system, including progressive farmers, the private sector, and NGOs.
- Identify and adapt conservation and precision agriculture-based cropping systems that build resilience to stresses from climate change, resource scarcity, and fluctuating market conditions.
- Explore options for farming systems diversification to optimize system productivity and resource-use efficiency; this may include introducing or expanding the roles of pulses, livestock, cotton, sugarcane, or vegetables in maize- and wheat-based cropping systems.
- Enable process-based field, laboratory, and simulation studies to understand how yield gaps can be bridged and why certain management practices are beneficial, and to extend the related findings effectively and efficiently to other locations.

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11. > 15% decline in the potential productivity of a production system; Katya, JC,, and PLG Vlek. 2000. Desertification—Concept, causes and amelioration. ZEF Discussion Papers on Development Policy 33, Center for Development Research, Bonn, Germany.
12. Sehgal, J, and IP Abrol. 1994. Soil degradation in India: Status and impact. New Delhi: Oxford & IBH Publishing Company.

- Work with plant breeders and seed companies to guarantee that new germplasm is well-matched to conservation agriculture and precision production practices that contribute to system intensification in different environments.
- Foster multi-disciplinary research—uniting the efforts of agronomists, entomologists, plant pathologists, water resource engineers, soil scientists, economists and the private sector—to ensure that challenges to sustainability are addressed with innovative production practices that promote long-term improvement of natural resource quality.
- Develop scale-appropriate conservation and precision agriculture equipment and techniques for 2- and 4-wheel tractors and for animal traction.
- With socioeconomists, build and evaluate robust decision support systems and knowledge delivery mechanisms that allow farmers to intensify cropping systems profitably and sustainably.

The Institute's visionary research will use novel measuring techniques and comprehensive approaches to quantify and model soil-plant-atmosphere processes for meaningful up- and, down-scaling of climate change scenarios. Endowed with state-of-the-art spectroscopic and electromagnetic instruments—including reflectance spectroscopy and ground-penetrating radar—the Institute's facilities will allow quick analyses of large numbers of soil and plant samples, ensure representative sampling, and provide vital information on surface reflectance, salinity ratings, rooting depth, and subsurface layer information. The Institute will also feature technologies such as eddy covariance flux towers (assorted heights), tunable diode and open-path lasers, and chemiluminescense, Free-Air CO2 Enrichment (FACE) and Free-Air Temperature Enrichment (FATE) facilities to study the impacts of conservation and precision agriculture and serve as educational facilities for students, researchers, and policymakers from South Asia and other parts of the world.

Socioeconomics research

Socioeconomics research will generate knowledge and institutional innovations. These will complement technology development and help target wheat and maize research for maximum benefits in sustainable productivity growth, diversification, and poverty reduction. Work will be conducted jointly with local partners, offering diverse training opportunities for researchers and young scientists, and focusing on the following areas:

- Effective targeting of technologies, particularly to benefit smallholders and resource poor farmers, setting research priorities for breeding and farming systems, and fostering timely delivery of inputs to smallholders, including rapid deployment of new germplasm and production technology.
- Analysis of trends and outlooks for productivity growth, changes in total factor productivity, and competitiveness in regional and global markets.
- Strategies for sustainable intensification and management of crop, land, and water resources in wheat and maize systems.
- Geographically-linked information on how climate change will affect livelihoods and ways for households to adapt and mitigate impacts.
- Analysis of drivers of adoption of new technologies and of emerging threats and opportunities, especially among South Asian countries.

- Adoption and impact studies to assess economic and environmental benefits of the Institute and partners' work; marginalization, equity, and the inclusiveness of productivity growth; and strategies for scaling up sustainable technology and institutional innovations.
- Institutional innovations that enhance farmer access to markets, credit, inputs, and extension services, and which stimulate demand for alternative uses.
- Current and future outlooks for wheat and maize and analysis of national and South Asian food security and trade issues.

Capacity building

The Borlaug Institute will serve as an international human resource development centre for maize and wheat R&D in South Asia. In collaboration with agricultural universities, national research institutes, and the private sector in India, the Borlaug Institute will provide:

- Training courses in applied maize and wheat breeding. These will focus on the use of up-to-date knowledge and modern tools to increase yield, stress tolerance, and resource-use efficiency in adapted germplasm.
- Applied training in combining and applying the principles of both conservation and precision agriculture and in catalysing and managing innovation platforms focused on the needs of progressive farmers.
- Socioeconomic training, including bio-economic modeling and policy analysis, market and value chain analysis, livelihood and vulnerability analysis, and technology adoption and impact assessment.
- Fellowships for highly-motivated researchers from the region.
- Opportunities for research on cutting-edge technologies—for example, next-generation genotyping, precision farming or climate change mitigation—for MSc and PhD students.
- Business training for staff of small- and intermediate-size seed enterprises.
- Regional workshops, seminars, and conferences for breeding and crop management also including topics such as intellectual property management, biosafety, regulatory compliance, and stewardship on a national, regional, and international basis.

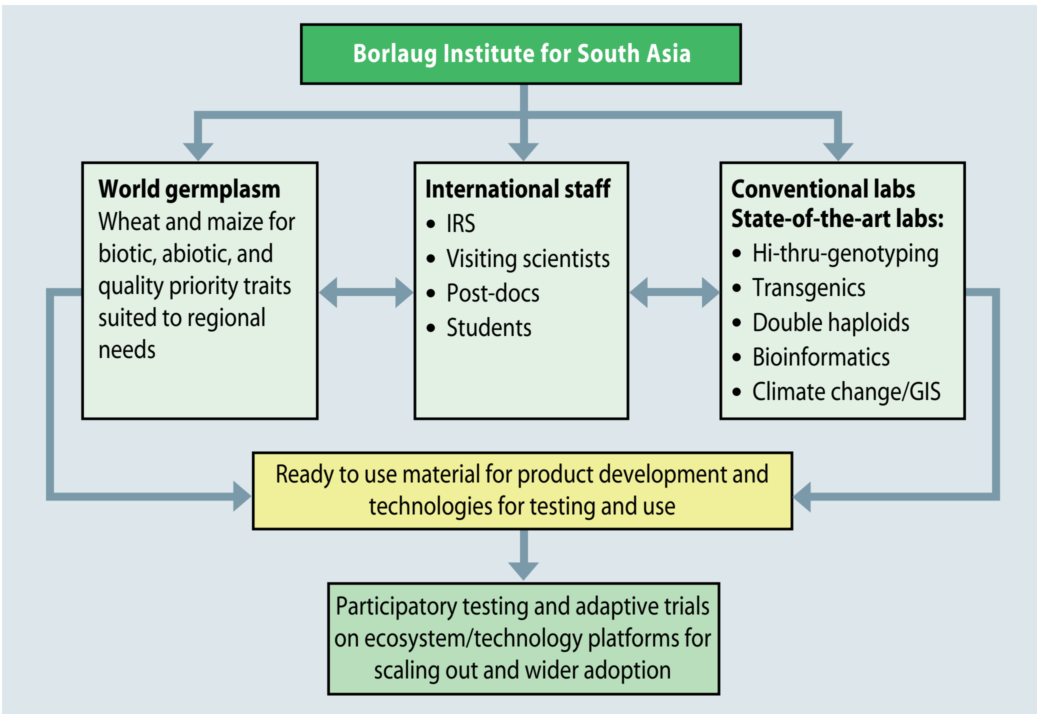
The presence of the numerous agricultural universities and research institutes in India will enhance the level and the quality of the interaction and allow MSc and PhD students and scholars to do their research with CIMMYT staff at the Borlaug Institute.

5. Logistics for the Borlaug Institute

The Borlaug Institute will operate as an international organization managed by CIMMYT. It will require land, facilities, and basic annual core funding from the government of India. The start-up investment will be Rs 150 crore (USD 32 million), plus Rs 35 crore (USD 7.5 million) of core funding for annual operations. Project funding from international donors is expected to more than double the Institute's annual operational budget and recruited scientists. Highly-integrated collaboration with the Indian Council for Agricultural Research (ICAR) will be defined through five-year "Workplans for Scientific and Technical Partnership on Maize and Wheat Systems". Governance of the Borlaug Institute will be the responsibility of the CIMMYT Board of Trustees in consultation with leaders / representatives of South Asian stakeholders though a biannual meeting on the Institute's agenda. The Institute will interact with members of collaborative research projects through joint planning, execution, and review of projects to implement its agenda. In the organization and management of the Borlaug Institute, CIMMYT will adhere to the following basic principles:

- Visionary research and demand driven product delivery in service to the poorest communities in South Asia.
- Enhanced food security in view of increasing climate change, resource scarcity and demands for quality.
- Regional and international cooperation among research and development institutions, non-governmental organizations, and the private sector.
- Free exchange of information, technologies, germplasm, and scientists.
- Human resource development through the chain from research to the marketing of cutting-edge products and technologies, and impact assessment.
- Application of international performance standards for research, management, biosafety and training.

Overview of the Borlaug Institute



Location

An appropriate location will be crucial for the efficiency and effectiveness of the Institute and should meet most of the following criteria:

- Provision by a state government of 200 ha of qualifying land for infrastructure development of the Institute's research fields, laboratories, experiment station, offices, training and conferencing facilities, hostels, and housing.
- Land relevant and suitable for maize- and wheat-related research and training activities, including relevance for accelerating progress towards food security and rural development under increasing stress from climate change and resource depletion.
- Close to an airport which is well connected to national and international destinations.
- Access to high-quality primary schooling, medical facilities, and having a peaceful and well-secured environment for staff.
- State government's willingness to support the Institute with adequate security on a long-term basis.
- Uninterrupted power supply and good telecommunication and internet connections.
- Approximately 10 ha each at 14 co/shared satellite locations spanning the range of major maize and wheat cropping systems projected to be severely impacted by climate change or other resource stresses. The satellite locations should be placed on existing Indian government research stations (9) and those of other participating South Asian countries (5).

It is suggested that the government of India ask maize and wheat producing states to suggest potential locations based on the above criteria. A committee of experts nominated by CIMMYT and the Government of India will advise on the ultimate location for the Institute and the locations of satellite activities within India.

Facilities

The Institute will have the following facilities, shared between the main Institute and satellite locations:

- Offices for 300 staff, visiting scientists and students.
- Housing for 20 international staff and 10 senior national staff.
- Guesthouse facilities for 50 visiting scientists and 50 students.
- Catering facilities for staff and visitors, including accommodations for major meetings.
- Laboratories and work areas for physiology, pathology, entomology, grain quality, soil analysis, high-throughput genotyping, bioinformatics, transgenics, and geographic information systems and monitoring of climate change mitigation efforts.
- Greenhouse facilities, including Level 1 Biosafety greenhouse facilities, screen houses, growth chambers, and rainout shelters with rhizotron.
- Work areas for seed processing and equipment and facilities maintenance.
- A minimum field area of 150 ha, with the necessary infrastructure to apply irrigation.

Field research stations

Field-based research will be conducted at the main Institute and at satellite locations in collaboration with partner institutes across India and South Asia.

Wheat

- Irrigated (Rabi) season nurseries including screening for diseases (cereal rusts, spot blotch, septoria) and for heat and drought tolerance.
- Off-season location for germplasm increase/screening nurseries.

Maize

- Main season (Kharif) trials and nurseries including screening for diseases (banded leaf and sheath blight, downy mildew, post-flowering stalk rots), insect pests (stem borers), and heat tolerance.
- Off season (Rabi) trials and nurseries including screening for yield potential, drought, and cold tolerance.

Cropping system satellite locations

Beyond the Institute location, additional cropping system satellites will be placed at 14 locations (9 in India) representative of the principal agro-ecosystems of South Asia. Collaborative work at these locations will include both on-farm and on-station work for which about 10 ha of experiment station land will be required at each site:

- Five locations spanning the rice-wheat systems of the Indus and Ganges basins, following a transect from west to east, with differences in rainfall, land-holding, poverty and secondary cropping systems, and system opportunities, including one site each in Pakistan and Bangladesh.
- Five sites representative of the upland mixed systems, including one location each in Sri Lanka, Bhutan, and Nepal.
- Four sites representative of rainfed mixed systems in northern, central, and southern India.

Staffing

The Institute will employ 20 internationally-recruited scientists and 300 locally-recruited staff, plus 50 visiting scientists and students. Twenty additional scientists will eventually be recruited and financed by other donors.

Internationally-recruited staff will comprise the following specializations: Leader of Borlaug Institute (1); Socioeconomists (2); agronomists (2); soil scientists (1); precision farming / mechanization specialists (1); wheat breeding/genetics/molecular breeding scientists (2); maize breeding/genetics/molecular breeding scientists (2); maize/wheat physiologists (2); maize/wheat pathologists (1); cereal chemists (1); quantitative geneticist/biometrician (1); biosafety/transgene management specialists (1); bioinformatics specialists (1); GIS-RS specialists (1); knowledge management and training specialists (1).

Locally-recruited personnel, visiting scientists, and students will include 60 post-graduate positions, 120 undergraduate positions, and 120 skilled staff, including Intellectual Property and marketing offices.

Capital and operating budgets for years 1-5 (USD '000)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Staffing	1,452	2,991	4,621	5,289	5,447	
Operational	1,188	2,447	3,781	4,327	4,457	
Institutional costs	660	1,360	2,101	2,404	2,476	
Infrastructure	11,127	7,418	464	464	464	
Equipment	2,691	6,728	4,037	2,243	2,243	
Total	**18,758**	**23,394**	**16,151**	**15,380**	**15,741**	
Staffing	30%	60%	90%	100%	100%	
Initial investment	13,818	14,146	4,037	0	0	32,000
Recurring costs	3,300	6,798	10,967	14,726	15,087	50,877

6. How can the Government of India support the creation and management of the Borlaug Institute?

Land: Solicit offers from maize and wheat growing states (major wheat and maize producing states are Punjab, Haryana, Uttar Pradesh, Uttarakhand, Bihar, and West Bengal) to provide free of cost 200 ha of land on a 100 year lease with provision to extend for use as the Institute's headquarters and primary research facility.

Funding: Provide a one-time grant for infrastructure development (farms, office, state-of-the-art laboratories, experiment station, training hostels, conferencing facilities, and housing facilities) estimated at Rs 150 crore (USD 32 million – see attached detailed budget spreadsheet). Provide annual core funding for operations of the Borlaug Institute of Rs 35 crore (USD 7.5 million). Project funding from international donors is expected to more than double the Institute's annual operational budget and number of recruited scientists. DG-ICAR & Secretary DARE and the Secretary Agriculture, GOI, are kindly requested to support CIMMYT in soliciting outside support.

Diplomatic status: Provide diplomatic status, fast-track visa passport and visa processing, and tax exemption for the Institute and the staff of other international centres hosted by the Institute. Facilitate transfer and exchange of international personnel.

In-kind support from the Government of India:

- Satellite locations at GoI research stations throughout India. Satellite locations in other South Asian countries will be financially supported by host nations or other donors.
- GoI phytosanitary/quarantine staff to clear germplasm within the Institute for distribution to cooperating countries.
- Support the Institute in the development of biosafety facilities.
- Collaborate and sanction the development of special projects funded by local and international donors.
- Provide establishment staff (CISF – central industrial security force).
- Accredit the Institute to facilitate linkages with selected universities for PhD degree studies.
- Revisit the ICAR/DARE- CIMMYT memorandum of agreement to conform with establishment of the Institute.
- Provide staff on deputation until such time that the Institute has its own staff.
- Uninterrupted power supplies at subsidized rates.
- Support to resolve clearance, approval and local disputes, if any.

In-kind support from hosting state government:

- Support access to state-of-the-art medical facilities and schooling near the Institute.
- Development and maintenance of access roads.
- Enhance the level of policing and local security for the Institute.
- Other support as suggested by the GoI.

Detailed budget spreadsheet

	Unit area	Capacity Staff	Capacity Area m2	Capacity Area ha	Unit space costs USD	Space costs USD	Equipment costs USD	Total costs USD	Equipment (beyond building fit out such as lab furniture, deionised water supply, safety equipment, electrical work)	Details and source of cost estimate
Total						18,545,000	13,455,000	32,000,000		
Facilities										
Office and meeting facilities	20	200	4,000		500	2,000,000	800,000	2,800,000	Furniture, air conditioners, computers, photocopier, scanner, phone/fax machines, printers, projectors, refrigerators, etc.	
Borlaug Library	300	1	300		500	150,000	50,000	200,000	Shelves, furniture, air conditioner, computers, photocopiers, scanners, printers	Interior work and furnishing: 50k
Housing	250	30	7,500		500	3,750,000	180,000	3,930,000		3 bedroom, 200 m^2 per house
Guesthouse	50	50	2,500		600	1,500,000	500,000	2,000,000		
Catering	10	125	1,250		500	625,000	300,000	925,000		
Laboratories										
Physiology	20x10		400		500	200,000	350,000	550,000	Hot-air oven (5), Greenseeker (4), Hand-held porometer (6), refrigerator (2), Deep freezer (2), Incubator (4), Spectrophotometer (2), Ultra-centrifuge (2), GC-MAS (2), Micro-scope with camera (2), HPLC (1), ELISA unit (1), Gel documentation unit (1), Electrophorasis set (3), Other minor equipements (<1000k) for Physiology lab (total USD20k)	100 k for basic lab outfit (fume hoods, lab furniture, deionised water supply, safety equipment, electrical work)
Pathology	20x10		300		500	150,000	150,000	300,000	Incubators (3), Stereomicroscopes (1), Compound microscope (1), Lyophilizer, Freezer (-80), Freezer (-20), Fridges, Cameras, Elisa reader, Fluorometer reader	100 k for basic lab outfit (fume hoods, lab furniture, deionised water supply, safety equipment, electrical work)
Entomology	20x10		200		500	100,000	50,000	150,000		100 k for basic lab outfit (fume hoods, lab furniture, deionised water supply, safety equipment, electrical work)
Grain quality	20x10		300		500	150,000	330,000	480,000	Wheat Grain Testing: Hectoliter weight (1.5K); moisture tester (Aprox. 2.5K); NIRS (with calibration software, NIRSystems, Foos-Tecator (Aprox 100K) for grain hardness/grain moisture and protein, grinders (Tecator, 2. Aprox 10K). Wheat Flour milling: Brabender Sr (Aprox. 40K)mill. Wheat Flour testing: SDS-sedimentation equipment (1 shaking rack, 3 vortex mixers. AProx 5K); protein analysis (semiautomatic, Mod. 2200 + digestor&accesories& scrubber (Aprox. 28K) Foss). Wheat Grain/flour protein fractionation: Dispensers, pipettes, glassware/plasticware, pHmeter (Aprox. 12K), two thermomixers and one thermoblock (Aprox. 9K); microcentrifuge (Aprox. 5K); Two electronic balances and two analytic balance (Aprox. 10K). Singel-dimension electrophoretic equipment (Protean, Bio-Rad) (Aprox. 15K). Two water circulation system (Aprox. 9K). Wheat Dough rheology: Mixograph (35g-flour sample, electronic recording (30K); Alveograph (with alveolink) (Aprox. 35K); microplate reader (16K); computers for balances and equipments (10K); Retsch miller (approx 15K); liophilizer (16K), Soxtec system (approx 20K), labware washing machine (approx 14K).	100 k for basic lab outfit (fume hoods, lab furniture, deionised water supply, safety, equipment electrical work)
Soil analysis	20x10		200		500	100,000	300,000	400,000	Aggregate Stability equipment, Atomic absorption spectrometer, Chemicals, Digestion Blocks (you will need this to digest the samples before running them in the AA and ICP, Drying oven, Gas chromatograph, Glasware (beaker, petri dishes etc.), Hardware and software for environmental monitoring and geo-spatial analysis, Hectoliter weight kit, Hydrometer, Inductively-coupled plasma analyser, Laboratory Mill Wiley Model ED-5, Latchet autoanalyzer, NIR lab spectrometer, Scales, Soil pressure plates, Stereoscopic microscope with digital camera, Total Organic Carbon/Total Nitrogen analyser	100 k for basic lab outfit (fume hoods, lab furniture, deionised water supply, safety equipment, electrical work)

	Unit area	Capacity Staff	Capacity Area m2	Capacity Area ha	Unit space costs USD	Space costs USD	Equipment costs USD	Total costs USD	Equipment (beyond building fit out such as lab furniture, deionised water supply, safety equipment, electrical work)	Details and source of cost estimate
Double haploids	10x10		100		500	50,000	75,000	125,000	Colchicine treatment, fume hood, planter, drip irrigation	100 k for basic lab outfit (fume hoods, lab furniture, deionised water supply, safety equipment, electrical work)
High-through put genotyping	40x10		500		500	250,000	2,250,000	2,500,000	Array tape system, centrifuges, liquid handlers, -80C freezer, pipetting, plate handlers, balances, thermocyclers, Kernel chipper (local design and manufacture), Next-gen sequencer, SNP genotyping system (Kbiosciences), Liquid robotics for molecular lab, capillary electrophoresis system	BECA: 600 m2 for 30 NRS; equipment costs from private sector
Bioinformatics & IT (Servers & printers)	20x10		300		500	150,000	800,000	950,000	Web server. Production and develoment database servers. Analysis server. Mail and file storage servers, Printers for each area. High speed network and switches. Fully equiped server room.	CIMMYT ICT Capital Expectiture plan 08-10 based on IT 100 users and not 200. CRIL bioinformatics intrastructure setup costs
Transgenic laboratory	20x10		200		500	100,000	750,000	850,000		200 k for basic lab outfit (fume hoods, lab furniture, deionised water supply, safety equipment, electrical work)
			2,500							
Work area										
Seed laboratory	20*150		3,000		350	1,050,000	1,000,000	2,050,000	Threshers, seed counters, shellers, computer, printer, photocopier, electronic scale, field scale, moisture meters, shelves	
Workshps, maintenance and utilities	20*100		2,000		350	700,000	2,500,000	3,200,000	Generator, water treatment, workshop, health and safety equipment	
Storage										
Cold room (4 C)	20*30		600		500	300,000	60,000	360,000	Shelves (68k), trays, containers	
Air conditiond storage area (18 C)	20*30		600		350	210,000	60,000	270,000	Shelves (34k), trays, containers	
Ambient temperature	20*50		1,000		350	350,000	100,000	450,000	Shelves, trays, containers	
Greenhouse facilities										
Level 1 Biosafety greenhouse facilities	20*30		600		1,400	840,000	100,000	940,000		BECA: 180 m2, USD 250,000
Growth chambers (wheat)	2*10		10		50,000	500,000		500,000		
Green house	20*50		1,000		400	400,000		400,000		
Screen house	20*100		2,000		100	200,000		200,000		
Rainout shelters with rhizoctrons	10*200		2,000		360	720,000		720,000		
Fields										
Irrigated fields				100	25,000	2,500,000	500,000	3,000,000	Irrigation equipment, tractors, field equipment, access roads, leveling, fencing, dam	
Rainfed				50	15,000	750,000	250,000	1,000,000	Tractors, field equipment, access roads, leveling, fencing	
Surroundings				50	15,000	750,000	100,000	850,000	Access roads, leveling, fencing, irrigation	
Transport							1,500,000	1,500,000		
Flux towers		3			200,000	0	400,000	400,000		