

**Research into Development: Assessing CGIAR Research  
Priorities from the Perspective of Development Challenges**

**First Draft**

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The Green Revolution of the 1970's changed perceptions about development as well as changing the trajectory of food production in Asia. In the initial instance, it reversed the pessimism in thinking about the largest development challenge of that period, namely how to ignite growth in the Asian agricultural sector, particularly in India. Additionally, the Green Revolution became something of a paradigm for agricultural development by putting investment in agricultural research and new technology at the core of the agricultural development process. The success of the high yielding rice and wheat varieties established the linkage between agricultural research investment and impacts on development outcomes, such as aggregate food production, rural poverty, and employment of landless labor. It precipitated a new field of academic enquiry encompassing the allocation of, the returns to, and the impacts of agricultural research investment. Finally, the Green Revolution justified the mobilization of international funding around the need for sustained investment in agricultural research capacity in the developing world and gave birth to the Consultative Group on International Agricultural Research, the CGIAR.

Investment requires continuing assessment, and particularly for international public funds that assessment has focused on effectiveness in moving about a billion of the world's population out of poverty (what has come to known as pro-poor development) and at the same time protecting the environment (or what is termed sustainable development). The UN's Millennium Development Goals are the most recent attempt by the development community and developing countries to set targets for a set of development outcomes. Other global reports feed into this assessment, including the Fourth Assessment Report of the International Panel on Climate Change, the Millennium Ecosystem Assessment and the IAASTD on agricultural research. The basic message across virtually all of these reports is that moving forward to 2050 the globe will find it increasingly difficult to balance concerns about poverty and social welfare, economic growth, and the state of the environment, all made more difficult by the progressively deepening effects of global climate change. The task is to find development paths that increasingly balance these three legs of the development stool and particularly that orient the economic growth process toward more favorable equity and environmental outcomes.

For the purposes of this paper, it is useful at the start to reflect on the eight Millennium Development Goals as the principal development challenges facing the developing world, particularly as many of the IARC's frame their strategy in terms of the contribution their research makes to the MDG's. Two of the MDG's, namely eradicating poverty and hunger and ensuring environmental sustainability fall clearly within the scope of agriculture, although the latter deals with a range of other issues including access to clean drinking water and sanitation. Fully three of the millennium goals target different health outcomes. One goal deals with universal primary education and one, potentially cuts across the three different sectors, but primarily targets female education. A central point here is that there is a certain asymmetry across these goals in relation to scope and scale of interventions needed to meet the targets. Halving the number of people living below the \$1 a day poverty line is a qualitatively different task than reducing by three-quarters the number of women dying in child birth. Although by no means easy and without constraints, it is still relatively clear, given the resources, how to design programs to do

the latter and deliver them through health services. However, it is far from clear how to achieve the former, as it essentially encompasses the whole process of economic development. Halving world poverty and malnutrition rates essentially requires an overall agricultural development strategy geared to these outcomes, in essence the essential focus of this paper. The paper will argue that indeed there are a range of difficult and interacting challenges that underlie an equitable and sustainable process of agricultural development.

The paper attempts to review the principal development challenges affecting agricultural development that come out of the recent publication of number of international assessments and reports and relate them to the research priorities of the CGIAR (Science Council, 2005). The first section provides a broad overview of the principal themes running through these reports and the CG research priorities are briefly discussed in relation to these themes. This section also includes a brief discussion of how research products are translated into development impacts. The following section then provides a review of principal development challenges. It is structured around a framework that is discussed in Appendix 1. In the final section, the paper then returns to how the CG might think about research priorities if it were based on development challenges rather than on aligning with scientific frontiers. The section concludes with a brief commentary on the organizational implications for the CG in trying to align priorities across both dimensions of its work.

### **The Intersection of Development Challenges and CGIAR Priorities**

Agricultural development across the tropics and sub-tropics faces a range of interconnected challenges. At the core of these challenges is how to ameliorate poverty and reduce malnutrition within very different economic contexts, each susceptible to quite different sets of drivers, resource constraints and institutions. There is an evolving consensus about *what* is required to achieve equitable growth, poverty reduction and declines in the number of malnourished-- the first, most central, and most difficult Millennium Development Goal. Lifting the majority of the poor above the poverty line requires firstly economic growth and secondly, and possibly just as critically, directed investments by government, the private sector, international agencies, and poor households themselves that guide development to bring the poor into the growth process. As the subsequent discussion on development challenges will suggest, the importance of economic growth is best expressed by the experience in Asia and the deteriorating situation in Africa where there has been a lack of growth. Nevertheless, the Latin American experience offers a warning that economic growth in and of itself is not sufficient for poverty reduction, which returns to the larger question of investment strategies that can guide the growth process toward larger impacts on the poor. Moreover, as a plethora of very recent reports suggests, with the 2008 World Development Report being possibly the most visible, investing in agriculture is critical both for initiating that growth process, but just as importantly, for ensuring that poverty rates continue to decline to negligible levels. However, the core development question, after more than half a century of thought focused on the problem, remains *how* to direct

policies and investment and the generation of technological, organizational and institutional innovations toward the achievement of these challenges.

The CGIAR was born out of the success of the Green Revolution. The history of that period would suggest that it was more serendipity than deliberate planning that allowed the dwarf rice and wheat varieties to have the extraordinary impact on productivity and incomes that occurred. The Green Revolution took place within the relatively unique context of the Asian staple food sector, which was heavily state-supported in terms of credit, extension, irrigation, input subsidies, and price controls, in essence all the preconditions necessary for a major technological advance to have the impacts it did. Nevertheless, the explicit link between agricultural research investment and impact on agricultural development objectives was forged and has motivated investments in the CGIAR over the past 35 years. Yet, it has not been possible to engineer the second green revolution in sub-Saharan Africa, at least not led *only* by the development of high yielding varieties adopted at the scale achieved by the original.

Using the Green Revolution as a model, the early research programs of the new international centers were organized almost solely around multi-disciplinary commodity research programs with breeding at their core, even though CIAT and IITA were originally set up with an explicit focus on farming systems in the humid tropics. The succeeding evolution of CGIAR research into farming systems, policy, natural resource management, and a range of other areas is a response to the imperative for impact and the realization that a range of complementary activities that support new production technologies was necessary to achieve that objective outside of the Asian irrigated sector. The latest articulation of this research for development agenda is found in *System Priorities for CGIAR Research 2005-2015*. In looking at the intersection of CGIAR priorities and development challenges, a set of overriding themes that arise from the analysis above will be developed and then related to the CG's priority set. This will be followed by some reflections on how to ensure to the extent possible that research is translated into development outcomes, by far the larger conundrum.

A couple observations might be made on the set of twenty research priorities. Firstly, the priorities divide relatively evenly between those focused on genetic improvement (8 priorities), those focused on systems research (8 priorities), and those on policy and institutions (4 priorities). There is often a clear correspondence between development challenges and either the systems or policy areas. That is less clear in the case of research directed towards genetic improvement. Secondly, the priorities combine some rather specific research areas, as for example "improving genetic tolerance to abiotic stresses", with a range of very broad research areas, as for example "agro-ecological intensification in low- and high-potential areas" or "improving research and development options to reduce rural poverty and vulnerability." The latter two potentially encompass a wide range of development challenges, while the former require some specificity in how they will be combined with other interventions to impact on some of the challenges discussed below. A clear one-to-one correspondence between research priorities and development challenges was never going to be possible. However, these large differences in the scope of the research across the priority set makes this task difficult,

but even more so, it raises the even more difficult problem of how to allocate resources across priorities of quite different scope.

### ***Overriding Development Themes and CGIAR Research Priorities***

The overriding theme running across the three “rural worlds” (see Appendix 1 for a discussion of this stratification) is that in most developing countries the agricultural frontier has essentially closed and where it has not, extending agriculture comes at very high costs to national and international public welfare. This theme lies at the heart of the Millennium Ecosystem Assessment and outside the energy sector is the core to the IPCC’s mitigation strategies. Yet the globe must balance that theme with the need to virtually double grain production in the next half century, driven partly by population growth but as well driven by the principal lever the world has to lift the bottom billion out of poverty, that is economic growth and the associated increase in incomes. Several corollary themes arise in the inherent trade-offs needed to balance these equations.

First, stabilizing land use will require that social benefits and costs of forests and rangelands come more into line with private benefits and costs. This will require both increases in productivity as well as internalization of the social benefits provided by the ecosystem services they provide. It is not clear that one will be sufficient without the other, especially when new markets arise, such as the recent discussion of sugarcane grown in the Amazon for biofuel production. In terms of CGIAR priorities, only the objective of promoting sustainable income from forests is in the explicit set of 20 priorities. The CG, working on the productivity side through improved management and development of markets for non-timber tree products, could build on the diverse pieces of work done on payment for ecosystem services in a variety of centers or it could partner with other organizations working on the subject. However, compared to forests and aquatic resources, the whole area of productivity of the rangelands is not explicitly set out as a priority, although elements are incorporated in other priorities. Arguably these systems have been more widely degraded than forest systems, given that they have been more widely utilized. Moreover, in Africa they are particularly critical in providing hydrological and biodiversity services, with some potential for carbon sequestration as well. Raising productivity of rangelands in Africa or Central Asia continues to be a daunting challenge.

Second, although the irrigated sector will continue to be critical for world food production, most of the future increases in staple food production will have to come from increased productivity in rainfed agriculture. This is clear in Asia, as well as Africa and Latin America. Moreover, stable increases in productivity will have to be achieved under increasing rainfall variability and rainfall intensity as a result of greenhouse warming and climate change. This area is a clear competitive advantage of the CGIAR. However, stable productivity gains in rainfed agriculture will come as much from improvement in crop, soil and pest management, as it will from genetic improvement. This is certainly

true in Africa and is as well represented by agricultural expansion into the Cerrado of Brazil. Yet, eight priorities are devoted principally to productivity enhancement through genetic improvement while other sources of productivity enhancement in rainfed agriculture are subsumed under the priority 4D, “Promoting sustainable agro-ecological intensification in low- and high-potential areas.”

This lack of balance between genetic approaches and management approaches is further brought into focus by one of the principal conclusions in reports such as the Millennium Ecosystem Assessment and the IAASTD on reducing the environmental costs of agricultural intensification. The argument is summarized from the report of cultivated systems in the MEA as follows:

Two key “win-win” strategies have emerged to increase economic benefits to farmers while reducing negative ecosystem aspects of cultivation: first, increasing the productivity of existing cropland through intensive management of specialized cropping systems and use of improved crop, soil, and water management practices and, second, designing more diverse crop and agroforestry systems that provide improved livelihood options as well as supporting greater levels of biological diversity and other environmental services at a local level.  
(Cassman and Wood, 2006)

Genetic improvement will be a necessary component of such agro-ecological intensification, but it will certainly not be sufficient, as the rapid adoption of conservation agriculture in Latin America suggests.

Third, there will be increasing trade-offs in the ability of national, regional, and global agricultural sectors to respond to the “value revolution”, especially in Asia, at the same time as fostering a “second green revolution” in cereal staples. The value revolution is adequately reflected in Priority Area 3, and movement into fruits and vegetables and intensification of livestock and fishery production systems is well justified by the rapidly changing and diversifying demand situation, especially in Asia, North Africa, and Middle East. There are two points in this regard. First, the two processes are not independent of each other, and how the value revolution plays out in each region will significantly influence the strategy necessary to increase staple food crop production. Second, there is a major question of the impacts of the value revolution on rural poverty. This is best reflected in the WDR distinction between market-oriented smallholders and what is termed the “large mass of subsistence farmers.” In Africa market-oriented smallholders are a very small subset of total farm families and in Asia the asset position of poor farm households will have to be radically changed for them to participate in new, high value markets. The WDR focuses on livestock as a vehicle for the landless in Asia, but the landless also have very little capital and there may be scale economies in intensive livestock systems. The participation of the large mass of subsistence farmers in the value revolution will depend critically on institutional and organizational innovations that foster such market integration.

Fourth, there will be a principal shift in policy approaches from traditional concerns about “getting prices right” to organizational and institutional innovations that facilitate efficient markets, smallholder participation, private sector investment, and sustainable resource management. Innovation is critical here, as governments tend to fall back on subsidies as a principal policy mechanism, when regulating markets is not an option. The CGIAR’s priority area 5 moves policy research very much in this direction. Ensuring that markets work for the poor is possibly the most critical policy issue across all three regions, particularly integration into expanding “value revolution” markets and developing efficient access to input and output markets in lagging areas and agrarian economies with limited road infrastructure. Much of the work on getting prices right was done in the 1990’s under structural adjustment and market liberalization. In Latin America and Asia, where the initial phases of agricultural growth were built through state intervention into markets and high protection, integration into the world economy in addition to expanding urban markets is aiding the process of structural transformation in the economy. Only sub-Saharan Africa faces the task of generating agricultural growth under conditions of essentially liberalized markets—even with some level of protection. This will require appropriate investment strategies by the public sector and institutional innovations such as low cost contract enforcement or organizational innovations such as reducing transaction costs in assembly and bulking through producer associations.

A large and important area that is not explicit in the priority set, although elements are found in research within forest and aquatic resource management, is that of developing institutional and organizational innovations for internalizing environmental costs inherent in agricultural production and paying land managers for environmental services. Areas such as carbon trading are expected to develop significantly in the future, offering possibilities for smallholders in the developing world. Similar work is needed in the area of hydrological and biodiversity services. Paying for environmental services helps to facilitate the supply of resources like water. Moreover, innovative types of organizational and institutional frameworks for sustainable resource management are needed in the areas of forestry, rangelands, and particularly water. Developing more effective mechanisms for pricing water and allocating it equitably will be essential for the most productive utilization of what will become an increasingly constrained resource. The latter is explicitly recognized in the priority set with a research thrust on increasing water productivity.

A final theme is that while market development and growth are necessary to reduce rural poverty, they are nevertheless not sufficient. As rural poverty rates decline the cost and intricacy of programs necessary to bring the next cohort out of poverty increases. Interventions in such cases revolve around shorter term safety nets and the relative efficiency of different targeting procedures and the longer term investment in the assets of the poor, particularly human capital aspects. In agrarian economies, governments don’t have the budget to support safety net programs and have yet to achieve the initial reductions in poverty from economic growth. Asia increasingly combines its public sector investment strategies with targeted safety net programs, while Latin America relies almost solely on such programs to address poverty. It is not apparent that the CGIAR has any particular comparative advantage in this area. However, one area that is

recommended by the Millennium Project's Task Force on Hunger is that of "improving nutrition for the chronically hungry and vulnerable" (UN Millennium Project, 2005). Developing synergies between agricultural and nutritional interventions within targeted, vulnerable populations is a possible area of work with direct impacts on the poor. Moreover, possibly the larger point here is that developing interventions or programs to achieve such impacts on the poor are quite context specific, as are the technological requirements of moving into lagging areas mostly dependent on rainfed agriculture. A final section explores a few of the implications of this point.

### ***Turning Research Products into Development Impacts***

Aligning research priorities with principal development challenges naturally begs the question of how the products of that research impact on those development challenges. As discussed above, the Green Revolution established an accountability relationship between investment in agricultural research and impact on principal development objectives. However, attempts at reinventing that green revolution has shown that there is no one-to-one correspondence between a research investment and impact on such objectives as increased agricultural growth or reduced rural poverty. Rather a range of interventions from more efficient markets, smallholder producer organizations, effective smallholder micro-credit programs, to extension methodologies for improved seeds as well as crop and soil management techniques are necessary to produce such impacts and only if such interventions can be provided at sufficient scale by an interacting set of institutions that themselves are not accountable to the CG centers. There is in essence the need to understand the necessary and sufficient conditions for research investments to be translated into development outcomes, and yet either those are not known with certainty or cannot be provided at sufficient levels in a coordinated manner. As will be argued in the last section of the paper, there is no effective structure for such coordination across the activities of the individual centers. The result is a fragmentary and dispersed set of research products that in turn are difficult to translate into development outcomes.

Nevertheless, some system for accountability of investment in the development process is necessary to guide future investment, which has been given recent emphasis by the entry of the newly created philanthropic foundations into the development arena while bringing with them the performance measures of the business community. The model that is often used is investment in the health sector—for example, William Easterly devotes a whole chapter in his book to development efforts in the health sector. Investments tend to be focused not on public health systems but on particular diseases, such as HIV, malaria, or tuberculosis, as reflected in the MDG's. Accountability is measured by, for example, the number of bednets distributed or anti-retrovirals administered and the reduction in number of malaria cases or the number of deaths from AIDS. The health sector defines its development objectives very narrowly and can very clearly relate investment to development impacts. Moreover, the periodic running of the Demographic and Health Surveys provides an instrument for evaluating these impacts across the developing world. However, that does not extend to the first MDG of reducing poverty and hunger. The number of poor or malnourished certainly can be measured, but the investments made ostensibly to reduce poverty can not be clearly attributed to the outcomes. This produces

a dilemma for investments in the agricultural sector by organizations such as the CGIAR. Either the CG radically narrows the objectives for which it is held accountable—what are currently referred to as development outcomes or direct impacts, such as number of farmers adopting a new variety or soil management technique—or as William Easterly argues, the objective becomes so large and so institutionally and politically complex that in the end accountability for any single organization is impossible, and therefore no organization is accountable.

Agriculture is not comparable to the delivery of social services--health or education is rather comparable to a much narrower evaluation of agricultural extension or advisory services. Agriculture is a large sector of the economy, and its development has an analogue in the very large question of how to develop the manufacturing sector in Africa. Even a relatively narrow question of how many farmers adopt a new variety is dependent on such factors as agroecological conditions, education of the farmer, availability of extension services, access to output markets, availability of credit, or efficiency of input markets. These were all factors in place in the Asian green revolution, but all to varying extents ineffective in sub-Saharan Africa. Therefore, how is investment in varietal research in Africa to be evaluated in terms of its potential impact, when it is so conditional on the existence of other preconditions? The development challenges sketched below all fall into this class of problem. They require a multiplicity of interventions with strong coordination, something provided by the state during the Asian green revolution and which must be provided by the market in the African context. The CGIAR now provides a significant subset of these necessary conditions, but they have to be closely tailored to the economic and institutional context. Research for development within the CGIAR will continue to be its own, internal challenge for some time to come. The paper returns to these issues in the last section.

### **A Review of Challenges Facing Agricultural Development to 2020**

The following three sections will undertake to identify development challenges specific to development of the agricultural sector across the developing world. This will be done within a framework that is laid out in some detail in Appendix 1. In brief, following on the World Development Report development challenges will be developed for different country groups at very different stages of economic growth and structural transformation in their economies. What are called agrarian, transforming and urban are country cohorts defined by the three different stages of development. To a very significant extent these cohorts are also congruent with the three principal regions, namely Africa, Asia, and Latin America. Development challenges, in turn, will be defined in terms of development goals, development drivers, resource constraints, and institutional and policy constraints. In essence, a development strategy for each region could be suggested by this structure. What will not be possible is to attach relative weights to these challenges, so as to define something of a ranking within a priority set. This reflects the interacting, systemic nature of development outcomes, development constraints and development drivers. The time frame is looking forward to 2020, although realizing that

world population is not projected to stabilize until 2050 and the major impacts of climate change are not projected to occur until the latter part of that period, as well.

### **Development Challenges within Agrarian Economies**

Agrarian economies are just that, economies still highly dependent on agriculture for employment, exports (where there are no mineral exports), and on average about 30% of GDP (Table 1 in the Appendix). GDP per capita is just under \$400 and rates of rural poverty are high in the range of 40 to 70%. Most, but not all, of these countries are in sub-Saharan Africa, virtually all are small countries, and a significant portion are land locked. As Paul Collier argues, they represent the principal development challenge for the next half century. As he further argues, these are also the countries with problems of governance, which raises a quandary for those development agencies that focus development aid only on countries with good governance. Moreover, these countries are late arrivals to the globalization processes that have helped transforming and urbanized economies to develop, particularly the development of labor-intensive, manufacturing industries focused on export. Thus, while there are inter related issues of governance and development of the manufacturing and urban sectors, agricultural development remains key to prospects for overall economic growth and social and economic development.

#### ***Challenges as Development Goals:***

*Challenge: The most critical development challenge of the next half century is how to generate smallholder-based, agricultural growth in agrarian economies that in turn leads to significant reductions in rural poverty and broader-based growth in the larger economy. After a couple decades of pessimism about the prospects for agricultural growth in sub-Saharan Africa and the resultant shift in focus and funding under Poverty Reduction Strategic Plans to rural health and education services (Eicher and Kane, 200\_), there is a reemerging consensus that investment in agriculture will be essential for any progress in achieving the Millennium Development Goals on the continent. This is best expressed in the World Bank's World Development Report 2008, but as well includes IFPRI's *The Future of Small Farms for Poverty Reduction and Growth*, the UN Millennium Project's report *Halving Hunger: It Can Be Done*, and the Gates and Rockefeller Foundations' *Africa's Turn: A New Green Revolution for the 21<sup>st</sup> Century*. This building consensus, however, has in turn generated a significant debate on *how* exactly growth in the agricultural sector is to be generated.*

There is consensus that the smallholder will be the key to both agricultural growth and rural poverty reduction. The tendency in some African countries, particularly in West Africa, in the 1970's and 1980's to promote large-scale agriculture has been largely discredited. Increasing smallholder productivity is now seen as an efficient pathway to agricultural growth, due to the more pervasive growth linkages, and for reduction of rural poverty, in essence the embodiment of what is now termed pro-poor growth. The debate rather now centers around what proportion of the smallholder population will participate in a market-led growth process, how smallholder development can as well contribute to

improved natural resource and environmental management, and related to this, the strategy underlying sources of smallholder productivity growth. There is as yet no model for sustained agricultural growth on the African continent, although the WDR suggests that Ghana is verging on sustained growth in its agricultural sector.

*Corollary Challenge: How to generate growth in the staple food sector.* Staple food crops bulk very large in the agricultural economies of agrarian countries. They, as well, are a critical component of the livelihoods of smallholder farmers. Generating growth in the staple-food sector is particularly critical to rural poverty reduction, and several modeling efforts by IFPRI (Omamo, et al, 2006; World Bank, 2007) have demonstrated the potential of productivity growth in food staples to lead the agricultural growth process and to make the largest contribution to rural poverty reduction. The argument is that traditional export crops do not offer the demand growth sufficient to generate the needed growth rates. On the other hand, non-traditional exports are focused on relatively high-value, high growth markets but these are very limited in size as both markets and as relative shares in African countries' agricultural sectors (Diao, et al, 2003). Nevertheless, with ineffective rural credit and extension systems and with inefficient marketing systems for what are often non-tradeable commodities, delivering technology and then maintaining price incentives across the agricultural sector during technology adoption will be especially difficult under liberalized market conditions.

*Corollary Challenge: How to generate growth in high population-density, high potential areas.* The poverty mapping work that has been done in a number of African countries suggests that while poverty rates are higher in marginal areas, the number of poor and the density of poor people are concentrated in the high potential areas where rural population densities approach those in Asia, but within the context of rainfed agriculture. A number of countries must generate growth where land resources are particularly constrained, such as Malawi, Rwanda, Burundi, and Ethiopia. Significant regions of Kenya and Nigeria are can also be included in these areas. Jayne and other colleagues at Michigan State University (Jayne, Mather, Mghenyi, 2006) argue that up to 70% of smallholders in countries such as Kenya and Malawi are currently net buyers, not sellers, of food staples, and do not have the resources of land, labor and capital to become major participants in staple food markets. Moreover, rapid technological change by the relatively better endowed farmers could further marginalize poorer households. Ensuring access of poorer household to both markets and to appropriate technologies will be essential to realizing pro-poor growth strategies in these high population density areas.

*Corollary Challenge: How to generate growth in low-population density, marginal agricultural areas.* Semi-arid areas dominate the agricultural sector of a range of countries in Africa, particularly those in the Sahel and southern Africa, in the latter region particularly Namibia, Botswana, Zimbabwe, and to a certain extent Tanzania. The agricultural sector faces especial constraints in these regions, particularly low and variable yields, high poverty rates, underdeveloped road infrastructure due to the low population densities, high transaction costs in product marketing, and underdeveloped input markets. It has been particularly difficult in these countries to link rural food grain markets dominated by sorghum and millet to expanding urban markets. In the Sahelian

countries, urban food demand is being met by imports, particularly rice and wheat, and in southern Africa, South African processing and supermarket companies are providing high quality maize and sometimes millet meal and flours. Market development is particularly difficult in these regions given very high transaction costs in assembly and bulking and the high, inter-seasonal variation in supplies. Livestock market development is complicated by the dominance of transhumance and pastoral production. Finally, increasing smallholder productivity under both rainfall and market uncertainty is complex.

*Corollary Challenge: How to reduce childhood malnutrition prior to an agricultural growth process.* Africa has the highest prevalence of childhood nutrition of around 35%. Although there has been a slight downward trend in prevalence (World Bank, 2007), there has been little progress made toward achieving the MDG target on childhood malnutrition. Agricultural growth and reduction in rural poverty is absolutely essential to making significant progress toward reducing malnutrition, but modeling results by IFPRI (World Bank/IFPRI, 2007) suggest that even reasonable growth will not reduce malnutrition at a rate sufficient to meet the MDG goal. The modeling suggests further progress could be made through complementary investments in such areas as female education, school lunch programs, and other similar types of safety nets. However, progress through these types of programs independent of growth and poverty reduction would swamp limited government budgets. The impacts of more explicit nutritional interventions such as biofortified food staples or increasing intakes of nutrient dense foods such as meat or vegetables on prevalence rates of malnourished children have not been systematically modeled nor have delivery systems been developed. The recommendations from *Halving Hunger* (2005), combine components of a smallholder-based growth strategy with nutritional safety-net interventions, with suggestions that the latter already represent a needed investment in future human capital on the continent. However, the high costs of delivering emergency relief and the increasing dependence on food aid are diverting resources from agricultural development efforts, introducing significant trade-offs between short and medium-term goals in the allocation of aid budgets.

#### ***Challenges as Development Drivers:***

There are a number of drivers of the agricultural development process where solutions lie outside the agricultural sector and therefore the remit of the CGIAR. However, adaptation to these drivers, often at the level of the smallholder household, are critical to maintaining or augmenting the growth process, and in that sense need both to be understood in terms of their impact on the growth process and to be planned for in terms of adaptive responses. In many cases, there are as well feedback loops or second generation effects from aggregate responses at the level of the agricultural sector that may influence these drivers. These drivers are specified as challenges primarily in terms of the impacts they potentially have on the growth process and the need for adaptive response.

*Challenge: Increasing investment in road and transport infrastructure could be a major spur to agricultural development and regional integration.* A large portion of agrarian economies are land locked, particularly many of the small countries in sub-Saharan Africa. At the same time road infrastructure is poorly maintained and not planned within a regional framework. For example, there is little connectivity between West Africa and East and Southern Africa or between Laos and Cambodia and the significant urban markets in China. This significantly increases the costs of inputs such as fertilizer—all, except for some phosphorous deposits, of which must be imported into Africa—and reduces the prices received by farmers. This results in a huge gap between import and export parity prices. Thus, “in Ethiopia the price of maize can fluctuate from around \$75 per ton (the export parity price) to \$225 per ton (the import parity price) without triggering international trade.” (WDR 2008, p.41) The African Development Bank is proposing the development of a sub-Saharan Africa road network (the Asian Development Bank has plans for a similar road network for the Mekong countries). Estimates by Buys, Deichmann, and Wheeler, (2006) suggest that trade within sub-Saharan countries (based on calculations of intercity, inter-country, and interregional trade) would increase from the present level of about \$10 billion a year to about \$30 billion, and with a significant shift from coastal trade to interregional trade across some of the poorest countries on the continent.

*Challenge: Africa has yet to go through a demographic transition toward lower birth rates and yet much of Africa does not have the land resources or urban absorptive capacity for its population to continue to grow at well over 2% per year.* Agrarian countries are the only ones where population growth remains high, where rural population continues to grow absolutely, and where the demographic transition to significantly lower birth rates has not yet occurred. Moreover, rates of rural-urban migration are much higher than many transforming countries, and yet urban employment and urban infrastructure is not being created at a rate sufficient to absorb these migrants. However, the AIDS epidemic has significantly shifted resources away from family planning programs to AIDS prevention and treatment. Yet, the challenge remains of reducing birth rates in essentially rural areas under conditions of high rates of poverty, relatively low levels of female education, and stresses on primary health care systems. Continued high rates of population growth is particularly an issue in areas of high, rural population densities, where farm sizes are now below levels that produce optimum efficiency and can guarantee subsistence levels, much less generate marketable surpluses, as for example has been demonstrated in the case of Malawi (Kydd, 200\_; Jayne, et al, 2006).

*Challenge: Reducing the disease burden in Africa is essential for improved labor productivity, ensuring pathways out of poverty, and sustainable livelihoods of rural households.* The disease burden on African rural populations remains unacceptably high. Malaria remains the largest contributor to mortality rates, but AIDS and the associated increase in tuberculosis have significantly lowered life expectancy in many African countries, especially in southern Africa. Climate change is increasing this burden, as malaria becomes established in the higher altitude, high population density areas of East Africa. AIDS treatment programs have put a renewed focus on the interaction between

appropriate nutrition and the ability of the immune system to respond. There are significant interactions between land use change, climate change, expansion of irrigation and increased disease burden. These issues are most pronounced in sub-Saharan Africa, and are reinforced by the high rates of rural poverty and malnutrition.

*Challenge: Climate change will have greater potential impacts on agrarian economies because of their higher social and economic vulnerability but other development drivers will be more important in the short to medium term on overall development.* The effects of climate change will be in some sense paradoxical, in that climate change itself will be less dramatic, at least in the tropical belt, than in other parts of the globe, but the impacts will be more severe given the agrarian structure of the economies, the high rates of rural poverty, and the high dependence on ecosystem services of rural households for their welfare. The recent IPCC report projects that rainfall is expected to decline in southern Africa and to increase in eastern Africa, although that is projected to occur principally in the higher altitude, higher rainfall areas. The expected effect on rainfall in the Sahel is uncertain. Overall the projection is for the semi-arid areas of the continent to get drier with increased rainfall variability (IPCC, Chapter 11, 2007). Although there are already “signatures” of global warming in temperature, and more recently, in rainfall patterns, the large changes in climate are not expected to occur until after 2025. Pursuing the development strategies laid out in this section will be essential for future adaptation of African rural households to the effects of climate change, in essence reducing their vulnerability to altered temperature and rainfall regimes. As noted in the IPCC report, “vulnerability to specific impacts of climate change will be most severe when and where they are felt together with stresses from other sources, (such as) poverty, unequal access to resources, food security, environmental degradation and risks from natural hazards.” (IPCC, Chapter 20) Combining adaptation with mitigation will be very possible in Africa, as soil carbon sequestration is expected to offer the 89% of the overall potential for mitigation in the agricultural sector (IPCC, Mitigation, Chapter 8, 2007)

### ***Challenges as Resource Constraints:***

*Challenge: Area expansion continues to be the predominate pathway for increases in food production, extending cultivation increasingly into marginal areas and putting pressure on other land uses critical for ecosystem services and maintenance of African biodiversity.* In sub-Saharan Africa yield increases contributed only 34% of the growth in food production, as compared to 80% in Asia and 71% globally. Africa remains dependent on expansion in area cultivated as the principal pathway for increases in food production. Such land use change comes at the expense of other natural resources. Olsen, et al (2006) summarize principal land use change in East Africa as follows, “the most significant land use changes (since the 1950’s) have been (a) an expansion of cropping into grazing areas in the semi-arid to sub-humid areas, (b) an expansion of rainfed and irrigated agriculture in wetlands and along streams especially in semi-arid areas, (c) a reduction in size of many woodlands and forests on land that is not protected, (d) an intensification of land use in areas already under crops in the humid areas, and (e) the maintenance of natural vegetation in most protected areas.” These changes have had

significant impact on the provision of ecosystem services and put increased emphasis on raising smallholder yields.

*Corollary Challenge: Soil degradation and nutrient depletion have been critical processes in the intensification of African farming systems, which in turn will require major investments in nutrients and soil organic matter in order to increase crop productivity.* Sub-Saharan Africa has the lowest rate of fertilizer use in the world, averaging just about 5 kg per hectare. This is far from being able to replace the nutrients extracted or leached in the production process, which in turn results in low yields, insufficient ground cover, loss of organic matter, and deterioration in soil health and productivity. The continued deterioration in Africa's soil resource will jeopardize any movement toward improving crop yields on the continent. However, there is some debate over exactly how to reverse this process, particularly whether to promote the development of fertilizer markets accessible to smallholders—all agree that this is necessary but some argue that it is also sufficient and is the most tactical path given the scale of the problem and the need to address it rapidly—or to focus on more integrated nutrient management approaches, with a particular focus on improving soil organic matter and soil structure—which as well would result in less leaching of nutrients into the environment. The essence of the argument is not so much on which tact is more relevant to Africa's needs, but rather which is more feasible in terms of improving crop yields at significant scale.

*Corollary Challenge: Africa relies on surface river flows for most of its water demand but flow patterns and equitable distribution of water are being impacted by changes in land use and land management, increased rates of abstraction, changes in precipitation, and water impoundment.* Projections are that water will be a limiting resource in southern Africa, eastern Africa, and the Sahel. Many, if not most, of the major river systems run through a complex of higher rainfall, upland areas and drier areas. As de Wit and Stankiewicz (2006) report, there is a non-linear relationship between precipitation and stream flow in areas receiving less than 1000mm of rainfall. Reductions in either precipitation or water penetration/run-off have an enhanced effect on reduced drainage and water availability in these areas. Southern Africa will face the most critical shortages, followed by eastern Africa and the Sahelian belt running from Senegal to Sudan (de Wit and Stankiewicz, 2006). Land use has been a critical factor affecting hydrology, but land management, particularly improvement of soil structure and vegetation cover in the grasslands and enhanced management in agricultural areas will be the critical factors influencing adaptation into the future. Equitable access to water will as well be impacted by increased demand for water for irrigation, including water harvesting, and for domestic use. Property rights governing surface water use in Africa are still in flux and this as well will be a major determinant of both utilization and access to water, especially between upland areas dominated by agriculture and lowland areas which in many parts of Africa are much drier.

*Corollary Challenge: The productivity of the African grasslands continues to be impacted by migration from higher rainfall areas and resultant cultivation, movement to sedentary lifestyles of pastoralists, increasing livestock populations and shifts between*

*large and small ruminants, increasing problems with access to water, and very high rates of rural poverty.* African drylands and grasslands provide a range of ecosystem services from charcoal and pasture to wildlife and biodiversity. Population and livestock increases, increased sedentary lifestyles and climate variability have put particular pressure on grasslands, with particular shifts from grass to shrubs, with a concomitant increase in soil compaction and erosion and reduced water infiltration. In many areas this has led to desertification, particularly in the Sahel and the Horn of Africa, although the recent “greening” of the Sahel derived from remote sensing suggests a complex interaction between climatic changes, human response, and vegetative cover. Very high rates of rural poverty together with few alternative livelihoods and the projected scarcity of freshwater in the Sahel, the Horn and southeastern Africa exacerbate the pressures on grasslands, while offering few alternatives to improve rangeland management and increase the flows of ecosystem services. The potential of developing biofuel production in these more marginal areas, as with the recent interest in jatropha, is yet another potential pressure on sustainable management of grasslands and semi-arid areas.

### ***Institutions and Policies as Development Challenges***

The area of policy and institutions becomes much more complex where markets do not function effectively, and this describes the condition of smallholder agriculture in most of sub-Saharan Africa. Three levers may be distinguished that attempt to mobilize investment and productivity improvement in the agricultural sector. The first is traditional economic policy, summarized by the phrase of “getting the prices right”. Structural adjustment and market liberalization in the 1990’s focused on achieving exactly this but while necessary, it was not sufficient to motivate the needed investments in input and output market development oriented to smallholders. This has led to a focus on two other areas, namely institutions (the rules of the game) and organizations (formal collective action). To a certain extent one of the three is often used to substitute for the other. For example, the lack of effective contracts underlying market exchange (rules of the game) has led to building trust and lower-level market functions within formal producer organizations. Or the perceived weakness in national research organizations has led to developing innovation systems through a focus on clearer financing rules governing organizational partnerships. Or the lack of effective extension systems has generated work on creating markets for advisory services, such as the experiment with NAADS in Uganda. Alternative approaches to such critical areas as extension services, agricultural research, and markets has produced significant debate over which is most effective, without much in the way of formal evaluation governing institutional, organizational, and policy change.

*Challenge: Development of efficient input and output markets that allow low cost access by smallholders will be essential to sustained and equitable growth in agricultural productivity.* Poor transport infrastructure, high rates of rural poverty, high transaction costs associated with market participation, and the high costs of product assembly and input distribution have resulted in high marketing margins, a subsistence orientation for

the majority of smallholders, extremely low utilization of critical inputs such as fertilizer, and lack of incentives for technology adoption. Estimates by Michigan State (Jayne, et al, 2006) suggest that upwards of 70% of smallholders, particularly in countries like Malawi, are net purchasers of basic staples. Poverty and resource constraints explain part of this, but lack of low cost market access is a major contributor to the inability to generate growth in smallholder productivity. More efficient and better integrated markets are essential in being able to respond to rising urban demand, to development of regional markets, or to participate in international markets. Development of the latter is principally focused on high-value crops where there are sufficient margins to meet the costs of assembly and transport. However, these are limited in size and are usually served by better resourced farmers. The most difficult markets within which to develop efficiencies are in staple food markets. As an example, in much of West Africa rising urban demand for cereals is being met by wheat and rice imports, at the expense of traditional grains such as sorghum and millet. Organizational and institutional innovations will be critical in the development of efficient markets that serve the majority of smallholders.

*Challenge: Agricultural growth within small countries, many of which are landlocked, will require regional integration of the agricultural economies with potential for both technological and economic spillovers.* Collier (2006) notes that “the world average (for economic spillovers to neighboring countries) for all countries, landlocked or not, is 0.4% (for each 1.0% growth in the neighboring country); for the non-African landlocked it is 0.7%, and the African landlocked it is 0.2%--virtually nothing.” Small African countries are losing significant growth potential by not being better integrated with their neighbors. This suggests that for African countries agricultural growth will first be based on better integration of internal markets, particularly rural-urban market linkages, second on regional market integration, and lastly on participation in international markets. ECOWAS, COMESA, and the East African Community are relatively recent attempts to rationalize tariff and non-tariff barriers, but progress, particularly in agriculture has been slow. This as well includes trade in such agricultural inputs as improved seeds, as well as access by agro-processors to regional markets, including regional investment. Moreover, redesign of the African road and rail network will facilitate such trade, as discussed above. Exploiting regional, agricultural comparative advantage, given the significant variation in land/labor ratios and agro-climatic potential within regions, offers scope for improved efficiencies and incomes, even when only a few countries have initiated growth.

*Challenge: National agricultural research and extension systems face a small country problem in Africa and since independence have gone through successive restructurings that have yet to produce productive, efficient systems that garner the requisite budgetary support.* Improved technology and management systems are seen as necessary for sustained increases in agricultural productivity and yet African governments continue to invest around 3% of fiscal budgets in agriculture, as compared to around 10% in Asia. This implies very little for agricultural research, and yet even for small countries the agricultural sector is very diverse, dependent on rainfed agriculture, and must deal with the complexity of smallholder farms. Research systems have gone through two major

restructurings in the 50 year period since independence and are on the verge of a third. First, colonial systems were restructured after independence, often dismantling regional research systems. Then in the 1980's research activities were consolidated in parastatal research organizations. Currently, efforts are underway to restructure along innovation system lines. The same has been true of extension systems, with the wholesale conversion of extension to Training and Visit systems in the 1980's and 1990's and their complete collapse at the turn of the present decade. Experimentation with design of extension systems continues. The search for a viable model of agricultural research and extension for African conditions persists and yet cyclical restructuring does not allow the consolidation and continuity of effort necessary for productivity of such long-term investments.

*Challenge: Lack of access to capital is a major constraint on investment and exchange across the agricultural sector from farm level through the marketing system to agroprocessing, thus limiting investment and growth across the sector.* Capital is highly constrained in African agriculture for different reasons. For smallholders it is the very high transaction costs inherent in allocating small loans with limited collateral. Micro-credit programs are only just being extended from urban, micro-enterprise to smallholder agriculture through such institutional innovations as warehouse receipt systems. On the other hand, within input and output markets working capital to finance commodity exchange through the value chain is limited by high risk associated with lack of contract enforcement. This constrains development of stockist networks for such items as fertilizer and limits developing scale economies in bulking and storage, particularly of food staples. Finally, investment capital for agroprocessing, seed companies, and other agricultural enterprises is limited within the banking sector by the higher returns and lower risks of urban investments. A multi-pronged, private-sector-led approach to financing the agricultural sector is needed. However, this assumes that the return on investment is sufficient to compete with returns in the rest of the economy and therefore that some of the other challenges discussed above are being met in concert with the roll out of financial programs.

### **Development Challenges within Transforming Economies**

Transforming countries, building on the agricultural growth achieved in the 1970's and 1980's and the significant investments in education, were the focal point of the globalization processes of the 1990's. Services and labor-intensive manufactured products, principally for export, became the principal contributor to growth, reinforced by inflows of capital and foreign investment. These countries achieved sustained growth rates of 6%, with rates rising to 8% in some, but with agriculture accounting for only 7 percent of total GDP growth in the 1993–2005 period (WDR 2007). As a result, “the incidence of people living in poverty fell from more than 50 percent in the 1970s to 18 percent in 2004—representing a decline in the overall number of poor of about 300 million (IFPRI, 2007).” As Peter Timmer (2007) has noted, this “economic growth was the most pro-poor in history and led to the most rapid and widespread reduction in poverty over four decades that has ever been witnessed.” However, the task is far from complete as the term transforming implies. IFPRI estimates that 600 million people in

Asia still live on less than US\$ 1 per day, most of these in South Asia (IFPRI, 2007). The challenge is not, as with the agrarian economies, in generating growth, but rather in managing the structural transformation and growth process to ensure continued poverty reduction as well as environmental sustainability. Both poverty and environment will be essentially addressed within the rural sector, and the agricultural sector will continue to play a critical role in setting food prices, determining national food security, and modulating rural-urban migration.

### ***Challenges as Development Goals***

*Challenge: Rapidly rising urban populations and incomes on the demand side and highly constrained land and water resources on the supply side are creating significant trade-offs in the ability of the agricultural sector to maintain food security at the same time as reducing rural poverty and improving environmental sustainability.* Market forces are moving the Asian agricultural sector to diversify into the production of income elastic food commodities at the same time that the structure of food marketing is moving toward scale economies in wholesaling and retailing, particularly the spectacular growth in supermarkets. This increases the farmer asset base necessary to participate in these markets, including specialized knowledge, equipment (particularly with livestock), market relationships, and improved management skills, that in turn creates differential access and participation rates in emerging new markets, especially as only limited portions of the farming population have accumulated these assets. Moreover, rural population will continue to grow, primarily in South Asia, putting continued downward pressure on farm size at a time when marketable surpluses per farm must increase. Smallholder-based and inclusive transformation of farming systems will require flexibility in land markets, adaptation to rising labor costs as employment is created in non-farm occupations, producer organization for scale economies in accessing markets, and a continuing focus on increasing productivity. At the same time, maintaining stable cereal prices will continue to be critical to allowing the poor to move out of poverty.

*Corollary Challenge: Strategies to reduce rural poverty will shift from broad based approaches to a focus on integrating lagging areas, where the rural poor are now concentrated, into the larger economy.* As the experience with rural poverty in Appalachia in the USA suggests, reducing poverty in lagging rural areas, where most of the rural poor are concentrated, requires alternative approaches to poverty reduction. In Asia, the task is huge, as half the world total of rural poor live there, primarily in South Asia. Areas such as the mountain areas of Vietnam, Thailand, and southern China, as well as the northern interior of China and the northern parts of Bangladesh (and the southeastern tip of the country), contain the bulk of the rural poor in those countries. However, the problem is probably best represented by the Eastern states and some of the central states of India. India has 80 million marginal farmers that depend on part time employment and 82 million landless laborers (WDR, Chapter 10). Strategies will have to focus on developing remunerative employment but where skill levels are relatively basic (also a major issue in North Africa), and on increasing farm productivity primarily under rainfed conditions. Otsuka (2007) in surveys in four Asian countries found that in areas impacted by the Green Revolution that farmers used increased income to invest in child

education which has led to second generation employment in higher skilled, non farm employment, that in turn has become a principal source of family income and been a major pathway out of poverty. Fan (2007) in a survey of returns on government investment found that agricultural research, education, and infrastructure had the greatest impacts on both agricultural growth and poverty reduction. Also, Fan found that “regional analysis conducted for China and India suggests that more (government) investments in many less-developed areas not only offer the largest poverty reduction per unit of spending, but also leads to the highest economic returns.” However, he also found limited returns to further investment in irrigation. Shifting government investments to lagging areas first in education and roads, where the largest contribution was to increase non-farm employment, and second in agricultural research where the impact was on productivity will be the basis of longer-term development of these poverty-prone areas.

*Corollary Challenge: Given the historical focus on national food security and staple cereal prices, Asia will face an increasing problem in how to meet continuing increases in cereal demand as rice, and to a lesser extent, wheat are displaced from irrigated agriculture.* The historical record of periodic famines in Asia has always put national food security at the top of the policy agenda. This is compounded by the fact that Asia accounts for 91% of global rice production, with very thin international markets, and 42% of global cereal production (Rosegrant, 2007). What happens in Asian cereal production has repercussions globally and this is reflected in an expected rise of international cereal prices of 21 to 41% (Rosegrant, 2007), particularly as North Africa and the Middle East, as well as sub-Saharan Africa, are projected to increase their imports and there are subsidies designed to shift grain to biofuel production in North America. Asia must continue to increase its production of cereals and this will have to be achieved under some very constraining conditions, namely that the availability of arable land will decline from urbanization and degradation, that cereal production will be increasingly displaced from irrigated lands, and therefore that increasing cereal yields in rainfed areas must be the principal path in both compensating for these constraints but as well meeting increasing demand. However, policies have been directed to maintaining rice in the irrigated sector, as Timmer (2007) notes “rice growing has been kept profitable through subsidies, virtually free irrigation water, price support and stabilization programs, and a well-developed rural infrastructure that ensured low marketing margins for rice.” A “green revolution” in the rainfed areas, for example the 27 million hectares of mostly rainfed land in Eastern India, will require reorientation of road infrastructure investments, agricultural research and extension, and cereal marketing systems, a transition that will be politically difficult to manage.

### ***Challenges as Development Drivers:***

*Challenge: Given the high rural population densities in Asia, the numbers of rural poor, the dependence of food systems on high yields, and the critical importance of river deltas for food production, climate change will have significant impacts on agriculture and food production.* Asia has already experienced more natural hazards than any other other region (IAASTD, Asia, 2007) and there is already statistical evidence to support a signature for climate change impacts on temperature and extreme weather events (Yohe,

et al, 2007). In South Asia the recent IPCC report predicts increases in daily extremes in minimum and maximum daily temperature, with night time temperatures increasing more rapidly. Night time temperature has a particular important effect on productivity of rice and wheat. Particularly, temperature has continued to be a barrier to movement of wheat into tropical areas and rises in the minimum night time temperature could result in major displacement of the crop out of the Indo-Gangetic Plain, as well a movement of the crop in China. Temperature rises, increased flooding, impacts on hydrology, sea level rise and problems with salinity, and increased reliance on rainfed areas will put increasing strain on rice production systems. Moreover, with the necessary increased reliance on rainfed systems for future cereal needs, increases in climate variability will make it particularly difficult to engineer sustainable improvements in productivity in these areas.

*Challenge: The very high population densities in Asia, the increasing livestock populations, especially of monogastrics and poultry, and the changes in livestock management systems are providing the conditions for both increases in existing zoonotic diseases and the potential for the emergence of new diseases with major human health consequences. Since 1980 greater than 35 new diseases have emerged in humans, many through transfer from animals or problems with maintenance of food or meat quality. SARS and avian influenza are examples of two of the more damaging diseases to arise in Asia. FAO estimates that in 2003 as much as one-third of the global meet trade was embargoed as a result of mad cow disease and avian influenza, together with some livestock diseases. At the same time the growth in livestock populations is occurring more in moister areas and closer to urban areas. In 2003 alone, more than 140 million chickens were culled in response to avian flu outbreaks. The consumption of wildlife meat in many parts of Asia adds to this risk. Managing livestock disease in Asia as livestock systems continue to intensify and grow in scale will be an increasing challenge both in terms of improving livestock productivity but as well limiting potential zoonotic outbreaks.*

### ***Challenges as Resource Constraints***

*Challenge: With over 80% of water resources in Asia being utilized for irrigation, little potential for growth in water supplies, and rapidly expanding demand for urban uses, water availability will be one of the most constraining factors on increased productivity in the irrigated sector. The irrigated sector in Asia will continue to serve as the stable “bread basket” of the continent, even as production patterns incorporate higher value crops. However, demand for water is rapidly increasing in Asia for industrial and urban domestic uses. More effective management of water resources will be central for efficient allocation of increasingly constrained water resources into the future. This will rest firstly on improving the efficiency of water use, with the expectation that full water control may have to be sacrificed. Both technological and management advances and introduction of pricing will be required. Second is ensuring appropriate land use in the upland areas, especially with the prospect of increasing flooding under climate change. Third is more effective management of water allocation in irrigation systems and reduction in water losses from the system. Possibly the most difficult area will be in rationalizing groundwater pumping, use, and recharge, particularly in South Asia.*

Groundwater is a common property resource with particular difficulties in collective management. The problem as well interacts with appropriate watershed management and effective recharge.

*Challenge: Managing the soil resource in both irrigated and rainfed areas in the process of continued intensification and the search for increased productivity will be increasingly complex as it introduces interacting nutrient, soil structure, and biological factors. As farmers have approached the yield potential of rice and wheat in the irrigated sector of Asia, the rate of yield increase has slowed and input efficiency, particularly of fertilizer, has declined in many areas. Moreover, in a range of long-term experiments there is evidence of declining yields of intensive rice systems (Ladha, et al, 2000) and significant decline in factor productivity. Farm-level evidence in the Indo-Gangetic plain in India also suggests increasing fertilizer use just to maintain yield. Some evidence suggests this is due to decreased nitrogen supply due to phenolic concentrations in the increasing soil organic matter (Cassman, 1999). Managing the soil resource under increasing intensification introduces another level of complexity in both the research and farmer management, as suggested by systems approaches to the problem. Moreover, soil degradation is also a factor in declining factor productivity, as reported by Hussain and Byerlee (200 ) in Pakistan.*

*Challenge: Increased rates of extraction of natural resources, intensified land use due to rising food demand, and increases in demand for ecosystem services, particularly hydrology and biodiversity, will require stabilization of forest conversion, effective management of aquatic resources, and appropriate valuation and payment for ecosystem services. In Southeast Asia the upland, often mountainous terrain provides and regulates the water supplies to the lowlands, particularly the river deltas where much of the irrigated agriculture is found and often across national boundaries. Asia is also the largest producer of cultivated fish, which as well depends on regulated hydrological supply. Rural poverty rates are very high in this region, and compared to Africa or Latin America population densities in the tropical rainforests are very high. Loss of forest cover comes at some potential cost in downstream water regulation and water quality, as well as increased flooding, and yet stabilizing forest cover is made more difficult by the increases in logging due to the rising demand for timber. Stabilizing land use and development of more sustainable upland agricultural systems will be critical for effective management of water resources and irrigation systems. Providing incentives for land managers to maintain forest cover will come both through some combination of managing forest products and payment for environmental services.*

### ***Institutions and Policies as Development Challenges***

*Challenge: The Asian political-economy of food security will determine whether governments will be able to shift policies from subsidies and protection to facilitating market-driven transformation of the agricultural sector. As Timmer (2007) notes, “by implementing a simple policy objective of stabilizing the real domestic price of rice—the operational definition of food security in these societies--most Asian countries saw*

the level of protection of their rice farmers rise sharply from the 1970s to the mid-1990s.” This policy bias benefits the larger farmer and often with the unexpected result of actually increasing rural poverty, as for example when Indonesia banned rice imports (Warr, 2005). Protection plus subsidies on water and fertilizer constrain the needed transformation of the agricultural sector toward diversification of the irrigated sector, intensification of the livestock sector, and appropriate allocation of water resources through effective pricing.

*Corollary Challenge: Asia faces the very difficult policy trade off of developing more efficient land markets to allow land consolidation and lower cost staple food production while risking undercutting a critical asset of the poor and increasing poverty, especially if there are not sufficient employment opportunities.* Asset distribution is a particularly strong determinant of the impacts of growth on rural poverty, no more so than land. Yet average farm size is now so small, especially in rainfed areas, that it cannot efficiently produce staple crops. Trends are that urban migration and non farm employment are productively absorbing an increasing number of rural poor, particularly those with skills. However, growth in these areas is still dwarfed by the mass of subsistence-oriented, small scale farms. The question is whether opening land markets will facilitate and moderate this transition or whether the gains from market-oriented farmers will be quickly reinvested in land, worsening land distribution faster than the production of alternative sources of income for those selling their land asset.

*Challenge: Building producer organizations and collective action at scale will be critical for sustainable resource management and smallholder access to new markets but constrained by education, gender bias, and lack of requisite administrative and financial skills.* Institutional and organizational innovations will be required where markets are not adequately developed or fully integrate the smallholder. Critical areas of common property management such as groundwater, aquatic resources, forests, and the northern and mountain rangelands will require capacitated community organizations and improved institutional arrangements. Allocative efficiency in the distribution of water resources will require both improved management, development of pricing mechanisms, and water user organizations, building on the enhanced potential for collective action found in irrigated areas. Probably the most difficult area will be in building financial and management expertise into producer groups that will facilitate access to supermarkets and agroprocessors operating with scale economies. While for each area there are good examples of how this might be achieved, the larger question will be how build such institutional and organizational changes at sufficient scale, where the building block is either community organization or collective action.

### **Development Challenges within Urbanizing Economies**

Urbanized, developing countries have, as the term implies, only about a quarter of the population still in the rural sector, or about where the US was in its structural transformation in the 1930's. These economies principally encompass Latin America, which in itself has had a relatively unique agricultural development history based on a very inequitable distribution of land, that is the major portion of the land controlled by

*latifundista* and most of the rural population concentrated in the *minifundia*. As the industrial sector developed, this led to very high rates of rural-urban migration and to a significant extent transferring rural poverty to urban poverty, where currently 60% of the poor reside. Large-scale agriculture is the engine of the agricultural sector, and the sector has consistently grown at 2.5% per year, with still sufficient yield and area capacity to be exploited. Structural adjustment opened these economies to international markets and the Latin American agricultural sector is now well integrated into global markets. Nevertheless, domestic markets still remain the main source of demand, accounting for three-quarters of overall output (WDR, Ch 10). The supermarket revolution was particularly rapid in Latin America and now accounts for over 60% of retail food sales.

### ***Challenges as Development Goals***

*Challenge: Latin America represents the limits to rural poverty reduction from economic growth, as the rural poverty rate is 46%, unchanged over 10 years and governments must turn to other approaches to alleviate persistent rural poverty.* Rural poverty in Latin America has largely become structural, the result of an inequitable growth process. There is a geographic concentration to poverty, represented by the Northeast of Brazil, large parts of the sierra of the Andean countries, and the mountain areas of Central America. However, given that migrants are those with human capital assets, those remaining tend to be women, the uneducated, and the aged. Strikingly, virtually half of the rural poor derive from indigenous populations. Economic options are increasingly limited. Latin America did not develop the village structures of Asia, which have become a loci for rural non-farm employment. Moreover, competing with an increasingly efficient large farm sector is only possible for very high value niche markets, where marketing channels are well developed and producers are well organized. There has been some success in limited areas with this approach in horticulture and dairy. However, the geographic areas where the poor reside in large part have limited infrastructure or face significant agroecological constraints. This has led to a focus on safety net type programs, where geographic targeting appears to perform best. These programs now constitute a major portion of the income of the rural poor, but the medium-term problem of how to transition out of poverty remains.

### ***Challenges as Development Drivers***

*Challenge: Given that the Latin American agricultural sector is well integrated into the global agricultural economy, the projected rise in world food prices with the potential to capitalize these in rising agricultural land values will put more pressure on extending agriculture into rangelands and tropical forests.* Latin America (together with sub-Saharan Africa) contains the largest stock of potentially arable land, virtually all of it in savanna and tropical rain forest. At the same time, the Amazon basin has over the last two decades been one of the largest contributors to the global increases in cultivated land (Cassman and Wood, 2006). Moreover, population growth in the Amazon basin that is due as much to internal population growth as to in migration. Land speculation continues to drive much of the clearance of forest, ostensibly for pasture and extensive beef production. Rising international grain prices, the continued expansion of the Brazilian

biofuels program into more marginal areas, and the resultant impact on land values will put continuing pressure on forest clearance. Moreover, given that Latin American markets are open to international trade, and benefits from agricultural research and new technologies are fully appropriated by producers, these gains over time will as well tend to be capitalized in land values.

### ***Resource Constraints as Development Challenges***

*Challenge: The conversion of rainforest to pasture in large parts of the Amazon Basin has left large stocks of unproductive, degraded pasture area, with significant questions about how to productively use that resource and its implications for further deforestation.* Extensive pasture establishment through conversion of rainforest has depended on nutrients held in the tree biomass. These soils are inherently infertile, with phosphorous being particularly limiting. With phosphorous offtake through animal sales and soil degradation from exposure to heavy rainfall, pasture productivity declines quite rapidly, leaving large stocks of relatively degraded land. Similar challenges were faced in the conversion of the cerrados to crop agriculture, requiring targeted research, heavy investment in inputs, and government subsidies that drove the process. Investing in pasture improvement does not offer the returns that crop agriculture does, and sugarcane for biofuel production is being considered as a possible crop for the degraded areas of the Amazon Basin. However, developing a profitable crop alternative for the Amazon runs the risk of speeding up forest conversion, particularly when costs of establishment are still cheaper on land in rainforest than on degraded land. Developing degraded land without putting increased pressure on further conversion remains a particularly difficult balancing act with few consistent mechanisms to control that balance.

### ***Institutions and Policies as Development Challenges***

*Challenge: While Latin America reduced tariff barriers and opened markets during the 1990's, governments still rely on subsidies of various kinds to foster growth in various commodity sectors and/or regions, often at the expense of investments that would broaden regional integration and market participation of the more disadvantaged.* “In 10 Latin American countries, the share of nonsocial subsidies in public expenditures in the rural sector was, on average, 48 percent between 1985 and 2000 (WDR, 2007).” Latin American countries have been quite successful in developing new commodity sectors first with tariff protection and subsidies and then opening them to international competitive competition, with a view to export. Soybeans and biofuels in Brazil are examples of this, while horticulture in Mexico, Central America, and Chile are examples of more recent, private sector led approaches to market development. As in Asia, subsidies are substituted for more creative, market-neutral policy approaches. With the democratization of Latin America, subsidies support the more politically and economically powerful, a problem not unfamiliar to developed countries to the North.

## **Towards a Framework That Links CG Research Priorities for Development**

Looking toward 2050, agricultural development must attempt to meet three principal objectives, namely maintaining growth in order to meet expected increases in global food demand, the need in a more crowded and globalized planet to reduce rural poverty, and at the same time the increasingly imperative to sustainably manage natural resources in order to maintain if not improve ecosystem function as well as to mitigate the causes of climate change. The agricultural development agenda has greatly expanded over the past fifty years, the task has become far more complex, and yet the need, from the reports reviewed in this brief paper, becomes ever more urgent. The question addressed in this last section is how to better align the research priorities of the CGIAR to ensure as significant a contribution as possible to the realization of a more equitable and sustainable future. This section will attempt to do this by first summarizing the critical objectives that the CGIAR might focus on as it deploys its work across the agricultural sectors of the developing world. The following section will briefly summarize critical research areas to meet these objectives. The paper will conclude with some principal organizational issues in meeting this research agenda.

*Better Specifying Strategic Objectives for the CGIAR:* The current set of priorities for the CGIAR are driven more by a critical sense of where the scientific frontier is evolving and less by a more strategic approach to aligning research priorities with a development agenda. How to marry these two quite different frameworks has been an issue from the inception of the CGIAR and will not be solved in this paper. Rather a set of priorities defined more from the development side will be framed. Table 2 sets out in a very stylized manner a set of principal development objectives as they apply to the different developing worlds or continents. Rather than the CG specifying its development objectives as simply poverty reduction, food security, and sustainable resource management, a clearer set of end objectives would potentially be useful in terms of focusing and integrating activities. What is highlighted in this table is the shift in development objectives as economies undergo structural transformation. Particularly, there is a shift in emphasis from equitable growth and poverty reduction to much more of a focus on sustainable resource management. This shift is not only reflected in principal challenges but as well changes in social priorities as economies urbanize and incomes increase. Environmental and resource management issues are given more weight by the electorate and as a result by policy makers.

**Table 2: Development Objectives and Regional Alignment**

Development Objectives	Regional Focus
Generating Smallholder-Led Growth	Africa
Linking Lagging Areas to Growth in the Larger Economy	Asia Selected Areas Latin America
Meeting Rising Food Demand Under Resource Constraints While Maintaining Ecosystem Services	Asia
Sustainable Management of Natural Resources and Closing the Private-Public Cost-Benefit Gap in Land Use Change	Latin America Southeast Asia

This shift in development focus could be seen as the inherent trade-off between growth and productivity objectives and investment in the environment. However, this is not the case and the argument is more subtle if the issue is analyzed across the development spectrum. Poor people's and poor countries' first priority is food production. Investment in natural resource management comes as both farmers and countries have the income generated by productivity growth. To the extent that sustainable resource management can be attained jointly with productivity growth, so much the better, but when there are trade-offs, the first priority is given to agricultural production. As growth occurs, the costs of environmental degradation put a break on productivity increases, as has occurred in some parts of Asia, and there is a move to find solutions that meet both objectives, usually at some increase in cost. As the agricultural economy becomes fully integrated into the global economy, then pressures come more from the majority urban population and objectives shift primarily to sustainably managing the resource base. The CGIAR has much more potential for uptake of its research results if it differentiates its research strategies by region and then more explicitly aligns its strategies with the dominant development needs in the region.

*Aligning Development Objectives and Research Priorities:* This section will develop a set of research priorities that follow from the development challenges. There is no clear analytical framework by which this is done and this particular set rests principally on the experience of the author and should be read as suggestive of what such a research priority

set would look like. What will be argued is that a research priority set derived from development challenges is not significantly divergent from the priority set that is primarily derived from aligning priorities with the advances available at the scientific frontier. However, it is organized very differently and that organization is key to bridging between a science driven priority set and a development driven priority set. Science for development is at the core of what the CGIAR does and yet it continues to struggle with how to find a bridge between the two domains. The reasoning in this paper will suggest developing something of a dual structure that provides that bridge. However, first a brief summary is presented of what such a development driven priority set might look like.

***Priority 1: Building Market, Technological, and Institutional Systems to Support Smallholder-Led Productivity Growth in Basic Staples.***

*Component 1: Improving efficiency of and smallholder access to staple food markets*

*Component 2: Developing technological components for sustained increases in productivity of rainfed cropping systems, usually on soils that have had high rates of nutrient depletion*

*Component 3: Developing cost-effective delivery systems for inputs, soil and crop management components and rural credit.*

*Component 4: Reducing the transactions costs inherent in smallholder markets and delivery systems through effective smallholder producer organizations that as well ensure access by poorer households.*

This priority area is targeted to the objective of smallholder growth in Africa and developing lagging areas in Asia. It posits that productivity growth in basic staples will be a critical component of such a growth process in Africa and in Asia is supported by the shift in staple production to rainfed areas. It is directed at alleviating poverty through growth in smallholder agriculture, with the component on integrating the poor through producer organizations ensuring that poorer households are brought into a market-driven growth process. This research area in essence recognizes that the production of technological components in and of themselves are not sufficient to generate productivity growth and need to be supported by an appropriate institutional framework, most critically effective access to markets. The critical question in these areas of high rural poverty rates and an often degraded resource base is what institutional framework will lead to smallholder investment in new technology and associated assets. As such, there are research issues associated with each of the four components but the larger questions are how the different components are made operational in either a phased or integrated manner. There will necessarily be a significant operations research component associated with monitoring progress with this research area, deployed at what might be termed meso-scale. Finally, it is critical to note that this research area largely aligns with any

adaptation program to climate change, where the first priority is developing a higher level of buffering capacity in local economies in areas of high rates of rural poverty.

***Priority 2: Developing supply chains for high-value crop and livestock commodities as growth nodes for emergent smallholder entrepreneurs.***

*Component 1: Improved production systems for horticulture, fruits, dairy, smallholder dairy, small livestock, and fisheries.*

*Component 2: Develop public-private partnerships for seed production and post-harvest technologies*

*Component 3: Test models for smallholder producer organizations that improve market efficiencies, availability of credit, and access to changing urban retail market structures*

*Component 4: Optimize nutritional impacts of improved access to horticultural and livestock products across nutritionally vulnerable groups*

How to harness the value revolution to the objective of reducing rural poverty is not clear. In Asia the significant increases in horticultural production and consumption is being led by both private seed companies doing breeding to produce hybrids and by rapid expansion in retailing of fresh vegetables, such as the Reliance Fresh chain in India. The highly competitive nature of these markets leads to a focus on more peri-urban production or those areas with favorable agroecologies, where producers have a sufficient asset base to participate in these markets. The same applies in trends in more intensive livestock production systems. How far these supply chains can be extended, for example, to service the high potential, high population density areas of Africa is an area that could potentially lead to broadening of the benefits in accessing these rapidly expanding markets, although from a much smaller base in Africa. As with the previous research area, the research would combine research on components with targeted operations research on extending supply chains into areas with higher poverty rates, although still ensuring critical profit margins for private sector investment.

***Priority 3: In meeting increasing food demand under increasing resource constraints sustained yield growth must as well reflect improved efficiencies in water, nutrient, and in some cases labor use, in the process reducing agriculture's ecological "footprint."***

*Component 1: Extending the yield frontier through genetic improvement*

*Component 2: Improved soil and vegetation management that maximizes nutrient retention and cycling and water retention and groundwater recharge*

*Component 3: Improved water efficiencies through drip technologies, reformed water management institutions, and pricing*

*Component 4: Landscape approaches to maximizing the ecosystem services derived from resource efficient agriculture and testing of payment systems to motivate investment*

This research area is principally targeted on Asia and integrates the need for productivity increases with more sustainable resource management in a period of increasing scarcity of water, higher energy and therefore nitrogen prices, potential rises in phosphorous prices with the exploitation of fixed high grade sources, and in at least some areas increases in labor prices with the eventual decline in absolute rural population figures. The focus of this research is on the irrigated sector and the higher potential rainfed areas. The research in this area is not as finely targeted as that in the previous two priority areas and relies significantly on appropriately functioning input and factor markets, including water, that in turn motivates investment in resource conserving technologies and management systems. Trade-offs in resource conserving management practices and rising labor costs may become apparent given the more labor intensive nature of many of these systems. This priority area very much is in the mold of induced innovation models. However, because of the more dispersed nature of this research theme, monitoring progress will as well be more dispersed, although it may focus on areas where resources are becoming highly constrained. Delivery systems for this type of work, including payment for ecosystem services, will require significant institutional innovation and testing.

***Priority 4: In meeting the critical need for sustained growth in productivity from rainfed areas crop and livestock production systems must adjust to increasing rainfall variability, higher intensity rainfall events, and rising temperatures and in a manner which improves stability of hydrological flows***

*Component 1: Developing soil and vegetation management systems that maximize water and nutrient retention and minimizes run-off at watershed scale or higher*

*Component 2: Improving investment in pasture and improved management of rangelands and silvipasture systems*

*Component 3: Better understanding of drought events combined with genetic improvement for drought tolerance and heat stress*

*Component 4: Developing more efficient input and output markets in lower population density areas and innovative approaches to crop insurance and risk management*

This research theme focuses on the more marginal areas of South Asia and parts of China and crop-livestock systems in the drier parts of Africa. The impacts of climate change are already being felt in these areas in terms of increased rainfall variability and these regions are projected to get drier over time. Nevertheless, these areas are expected to contribute to increased agricultural production principally through increased productivity, although from a relatively low level. Moreover, poverty rates in these areas are usually some of the highest. Increased productivity and yield stability will come principally from improved management of the resource base, with additional benefits from more stable

crop varieties. The needed investments producers will rely on improvements in crop and livestock marketing and reducing risk, possibly through crop insurance or other risk management techniques. Development of these areas has been problematic in the past, with climate change exacerbating the problem. Nevertheless, public investments in these areas appear to have a high return in South Asia. As with theme 3, monitoring of progress in this area will be quite dispersed with probably the need to focus more monitoring clearly specified outcomes rather than on impacts.

***Priority 5: Sustainable management of natural resources is needed to preserve ecosystem function and mitigate climate change and can be provided through increasing productivity in terms of harvestable products and closing the gap between public and private cost and benefits in the conversion of natural ecosystems.***

*Component 1: At the forest margins develop an integrated approach to sustainably managing converted land and sustainable product harvesting in natural forest with an understanding of the role of community and individual tenure arrangements.*

*Component 2: Develop systems for measuring and valuing ecosystem services arising from forest, aquatic, and agricultural mosaics or landscapes as well as the systems for payments for these services through collective institutional arrangements*

*Component 3: Develop systems for planning and managing water resource development and allocation at basin scale and below*

This research theme applies principally to Latin America, the Greater Mekong Region and Indonesia. Managing forest resources, hydrology and welfare of rural populations in the forest margins is a particular problem as institutional structures tend to be relatively weak. A significant amount of research has been done on better understanding the dynamics of the problem but there is less clarity as to how to reduce pressure on forests through deployment of sustainable management systems at scale. Alternative governance systems can play a key role in this process. Because of the need to first understand the problem through such mechanisms as the System Wide Program on Alternatives to Slash and Burn there has been less thought given to how to set up clear benchmarks and monitoring systems in this area. Because this area deals with quite complex biological and management systems, clear outcomes are often difficult to establish. A principal task will be in moving from a pure research mode to much more of an operations research mode in establishing clear frameworks for evaluating intervention points and progress in the area of sustainable resource management.

#### *Organizational Implications for the CGIAR*

The topics covered in the priority set laid out above are not exceedingly different from the priorities laid out in the Science Council's priority set. However, they are organized very differently. The Science Council's priority set reflect the current program organization of the CGIAR, running from germplasm to breeding to production systems to natural resources to policy and institutions. These research programs are an amalgam

of research programs that come from individual international centers who in turn organize their research around crop, ecoregion, or natural resource mandates, virtually all with a global purview. These are necessary and basic building blocks for a research system that focuses on increasing productivity and improving natural resource management in the developing world. However, it is difficult to overlay a problem framework on this structure and as a result difficult to assess progress toward, much less impact on, the end goal of reducing poverty. Moreover, with centers framing the development of their research programs around how to implement a global mandate, for example, for rice or livestock research, there has been little facility to embed the research planning process within overall agricultural development strategies, especially where each region has very different needs. This paper has attempted to develop such a problem framework, and the question of how it overlays on the current work of the CG system has as its core the question of how to optimally organize the research effort. In the current parlance of impact assessment, the problem is not just how to produce research outputs but how to strategically organize them into development outcomes that will then provide as high a probability as possible of generating impacts on end beneficiaries. An implicit argument in this paper is that the CG system has virtually all the basic outputs that go into producing these development outcomes but it lacks the organizational structures that can assemble and test them within an overall strategy.

There have been two different organizational mechanisms that have attempted to move the CG to developing such a capacity. The first is the African Challenge Program. This does not represent an organizational change but rather to a certain extent a test of the idea of how to build a platform for the integration of different technology, resource management and market interventions. This might be seen as a test of more flexible institutional arrangements, constructed on the basis of competitive grants. The transaction costs in this program have been found to be very high, with several years spent just in the planning and organization. The other approach, that as well is in the early stages of development, are the two Regional Programs for Collective Action in Africa. These too are being built around a central coordinating and facilitating unit with reliance on special project funding. There is a question of whether a more, dedicated core capacity is needed to undertake this type of work and whether the approach should be one of networking across different centers in similar areas of work such as markets—the mode of operation of the current regional centers—, or whether research programs could be transferred, possibly for limited periods of time, into the regional programs to give them more dedicated staff and the ability to move outside of framing the problem purely in terms of the mandates of the participating centers. The latter will probably be necessary, but the most appropriate organizational form still requires adequate specification and testing. That issue is a topic for future debate and goes well beyond the brief of this paper.

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## Appendix 1: A Framework within Which to Assess Agricultural Development Challenges

This section sets out a conceptual framework within which to understand development challenges that impinge on the work of the CGIAR. This framework is structured around two principal elements. The first is that over the last 40 years (ie since the Green Revolution) there have been significant differences across the developing world in growth and economic transformation. This has resulted in countries with very different economic structures and very significant differences in development challenges. Paul Collier in his recent book, *The Bottom Billion* (2007), argues that there is a bottom cohort of 58 countries that are small, have stagnated economically, and lie at the bottom of any development index rankings. These countries contain about 1 billion people and face development challenges that are structurally different from the rest of the “developing” world. He describes the issue as follows:

The problems these countries have are very different from those we have addressed for the past four decades in what we have called “developing countries”—that is, virtually all countries besides the most developed, which account for only one-sixth of the earth’s people. For all this time we have defined developing countries so as to encompass five billion of the six billion people in the world. But not all developing countries are the same. Those where development has failed face intractable problems not found in the countries that are succeeding. We have, in fact, done the easier part of global development; finishing the job now gets more difficult. (p. xi)

The World Bank’s *World Development Report 2008*, which focuses on the role of the agricultural sector in development, also recognizes the need to differentiate countries in terms of agricultural development strategies and suggests three distinct “rural worlds”. These are characterized as follows:

***Agriculture-based countries***—Agriculture is a major source of growth, accounting for 32 percent of GDP growth on average—mainly because agriculture is a large share of GDP—and most of the poor are in rural areas (70 percent). This group of countries has 417 million rural inhabitants, mainly in Sub-Saharan countries. Eighty-two percent of the rural sub-Saharan population lives in agriculture-based countries.

***Transforming countries***—Agriculture is no longer a major source of economic growth, contributing on average only 7 percent to GDP growth, but poverty remains overwhelmingly rural (79 percent of all poor). This group, typified by China, India, Indonesia, Morocco, and Thailand, has more than 2.2 billion rural inhabitants. Ninety-eight percent of the rural population in South Asia, 96 percent in East Asia and the Pacific, and 92 percent in the Middle East and North Africa are in transforming countries.

*Urbanized countries*—Agriculture contributes directly even less to economic growth, 5 percent on average, and poverty is mostly urban. Even so, rural areas still have 39 percent of the poor, and agribusiness and the food industry account for as much as one third of GDP. Included in this group with 255 million rural inhabitants are most countries in Latin America and the Caribbean, and Eastern Europe and Central Asia. Eighty-eight percent of the rural populations in both regions are in urbanized countries. (World Development Report 2008)

The development challenges facing countries between the three groups are very different and agricultural development strategies need to be designed within these very different contexts. Moreover, these categories are relatively congruent, although not completely, with the three continental regions, ie sub-Saharan Africa, Asia, and Latin America and the Caribbean (see Table 1). The first category is as well congruent with Collier's bottom billion, except that Central Asia is included in the latter, which may indicate that this region may require some differentiation as well. This paper, however, will adopt the WDR categorization and will differentiate development challenges by these different development contexts.

**Table 1.1 Demographic and economic characteristics of three country types, 2005**

	Agriculture-based countries	Transforming countries	Urbanized countries
<b>Population</b>			
Total (millions)	615	3,510	965
Rural (millions)	417	2,220	255
Share of rural population (%)	68	63	26
Annual population growth, 1993–2005 (%)	2.5	1.4	1.0
<b>Geographical distribution of rural population (%)</b>			
Sub-Saharan Africa	82.2	13.6	4.2
South Asia	2.2	97.8	0
East Asia and Pacific Islands	0.9	96.1	2.9
Middle East and North Africa	8	92	0
Eastern Europe and Central Asia	0	12	88
Latin America and Caribbean	2.2	9.7	88.1
<b>Labor force (in 2004)</b>			
Total (millions)	266	1,780	447
Agricultural (millions)	172	1,020	82
Share of agriculture (%)	65	57	18
<b>Economy</b>			
GDP per capita (2000 US\$)	379	1,068	3,489
Annual GDP growth, 1993–2005 (%)	3.7	6.3	2.6
<b>Agriculture</b>			
Agriculture value added per capita (2000 US\$)	111	142	215
Share of agriculture in GDP (%)	29	13	6
Agriculture's contribution to growth, 1993–2005 (%)	32	7	5
Annual agricultural GDP growth, 1993–2005 (%)	4	2.9	2.2
Annual nonagricultural GDP growth, 1993–2005 (%)	3.5	7	2.7

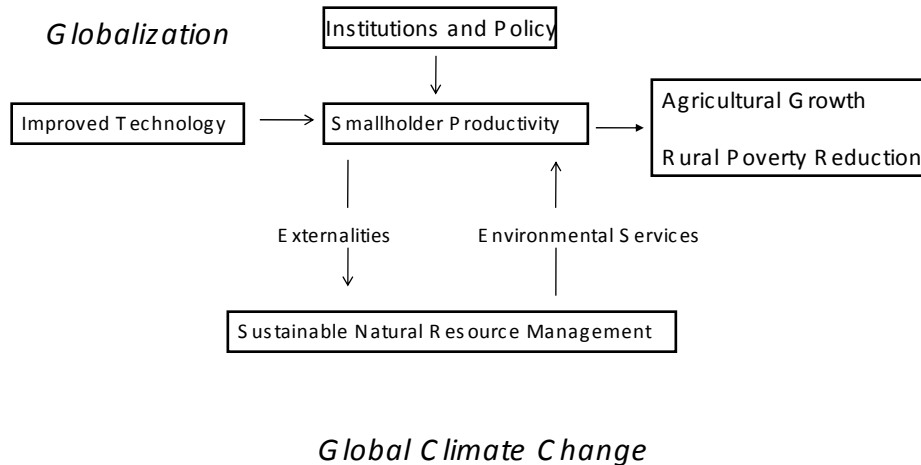
*Sources:* Labor force data: FAO (2006a). Other data: World Bank (2006y).

*Note:* Averages are based on 74 countries with at least 5 million people, except for agriculture value added, which is based on 71 countries because of missing information. Data are for 2005 unless otherwise noted.

Source: World Development Report 2008

The other element in the conceptual framework is to recognize that agricultural development is a complex of interacting elements, often with very strong feedback loops, in essence a system. The broad components of an agricultural development system are represented in Figure 1. Improvements in smallholder productivity are at the core of an agricultural development strategy that attempts to generate both agricultural growth and reductions in rural poverty. This is particularly so in sub-Saharan Africa and South Asia where the rural poor number 220 and 410 million respectively, and especially for countries with agrarian economic structures (World Bank, 2007b). In sub-Saharan Africa it is estimated that 90% of agriculture production derives from smallholders, as compared to India where 40% of food grain production comes from farmers with less than 2 ha. Thus, Figure 1 is mostly relevant to agriculture-based and transforming economies.

Figure 1: Framework for the Evaluation of Challenges in Agricultural Development



The figure as well represents the expanding scope of CGIAR research activity over the last three decades. The Green Revolution “paradigm” of the 1970’s focused on a relatively narrow and linear relationship between improved crop and livestock production technologies, increases in smallholder productivity, and the impacts of that on agricultural growth and reduction of rural poverty. This was the era of the multi-disciplinary, crop research program, which was principally organized around genetic improvement. However, the relatively easy yield gains of that period were not readily replicated in other crops and in the rainfed areas. This led to an expansion in scope (and number of IARC’s) in the 1980’s to policy and institutions. The Bruntland report on sustainable development motivated the expansion of the system to the area of natural resource management in the 1990’s. Since then the number of centers has actually declined with two mergers but the scope of the individual centers continued to expand into markets, nutrition, health, and climate change among others. The debate over research for development was only partly about where the IARC’s positioned themselves in the research to impact continuum (Science Council, 2006) but just as importantly about the scope of the research necessary to have impact in such difficult circumstances as those in agriculture-based countries. In essence the development agenda has expanded over this period, and the IARC’s have both led and responded in the process by expanding their work to a much more complex system than that pertaining during the Green Revolution. Figure 1 then is a highly summarized representation of the research for development agenda as currently pursued by the CGIAR.

At this point it is now necessary to be more specific about how to define a development challenge. Thus, are development challenges defined at the level of broad development goals such as generating agricultural growth in African economies or reducing rural poverty in South Asia or more at the level of increasing smallholder productivity in

rainfed agriculture in Africa? However, even the latter leads to challenges such as improving soil productivity in African farming systems. Moreover, this is in turn dependent on developing fertilizer markets in Africa and in the process ensuring smallholder access, potentially through fertilizer subsidies. In the literature, all of these are identified as a critical development challenge. On the other hand, such a structure suggests a hierarchical evaluation structure of development goal, development outcomes, and development outputs. William Easterly (200\_) has argued that defining aid and development programs in terms of broad development goals diffuses accountability and that effectiveness of international aid investments should instead be defined at the level of development outputs. Nevertheless, each level is relevant to the work of the CGIAR, even as a producer of international public goods—that is, the objective is not just on expanding knowledge but how that knowledge is translated into development outcomes and impacts. The principal point is that a simple list of development challenges is not very useful, but rather, the argument here is that such challenges are best arrayed within a systems framework that articulates a development strategy for each of the three “rural worlds” defined above. For the purposes of this report, challenges will therefore be separated into development goals, development drivers, resource constraints, and institutional and policy constraints.

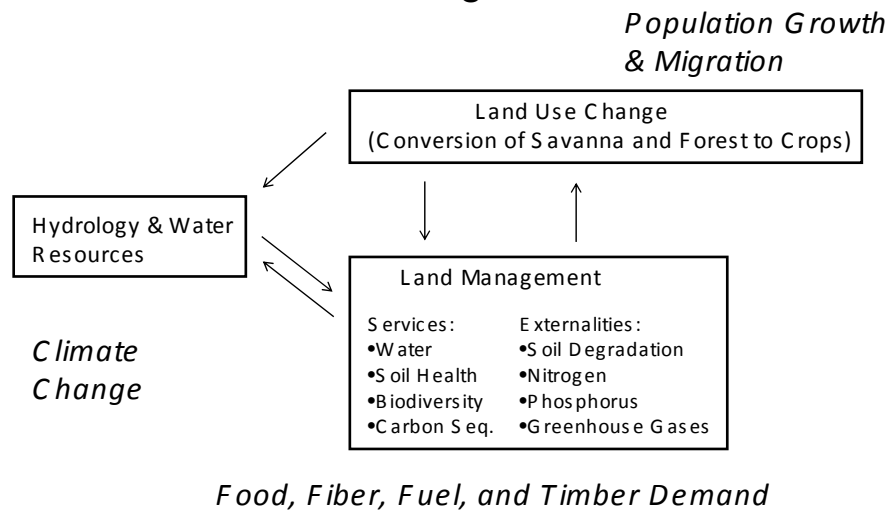
Each of the boxes in Figure 1 is in essence its own black box. It is as well useful to unpack at least two of these, particularly the boxes on natural resource management and on policy and institutions. Figure 2 explores in more detail the area of natural resource management. This has been an area of increasing global focus as reflected in the Millennium Ecosystem Assessment. A particular focus of that assessment was the increased pressure that an expanding and intensifying global agricultural sector is putting on ecosystem function within forest, aquatic, and grassland ecosystems, on climate change, and on demand for environmental services, especially water. Cultivated systems occupy 24% of the Earth’s terrestrial area (MEA, 2006) and including pastures, about a third of the area (CIESIN, 2002). Over the past century expansion of cultivated land doubled, while in the developing countries half the land cover conversion occurred in the last 50 years (CIESIN, 2002). However, in that same period global food production shifted significantly from relying on area expansion to increasing productivity of existing agricultural land. “Globally 78% of the increase in crop output between 1961 and 1999 was attributable to yield increases and 22% to expansion of harvestable area.”

The increasing reliance on increasing productivity, however, has come with appropriation of other resources, particularly water, and with externalities associated with the rapid increase in the use of inorganic fertilizers. The impact of agriculture vis-à-vis water is best summarized as follows:

Of the 9,000–12,500 cubic kilometers of surface water estimated to be available globally for use each year, between 3,500 and 3,700 cubic kilometers were withdrawn in 1995. Of that total, about 70% was withdrawn for irrigation. The share of extracted water used for agriculture ranges from 87% in low-income countries to 74% in middle-income

countries and 30% in high-income countries. By 2002, there were 276 million hectares of irrigated cropland globally—five times more than at the beginning of the twentieth century. While this irrigated area represents only 18% of all croplands, irrigated agriculture provides about 40% of the global food supply. (MEA, 2006)

**Figure 2: Framework for the Evaluation of Challenges in Natural Resource Management**



However, more extensive approaches to expanding agricultural output in Latin America and Africa and more intensive approaches to increasing crop production in Asia and livestock production in the developed world are leading to increasing contributions to greenhouse gases. Agriculture now accounts for 10-12% of all anthropogenic greenhouse gas emissions (IPCC, 2007) and the prognosis is that emissions from the agricultural sector will increase over the foreseeable future.

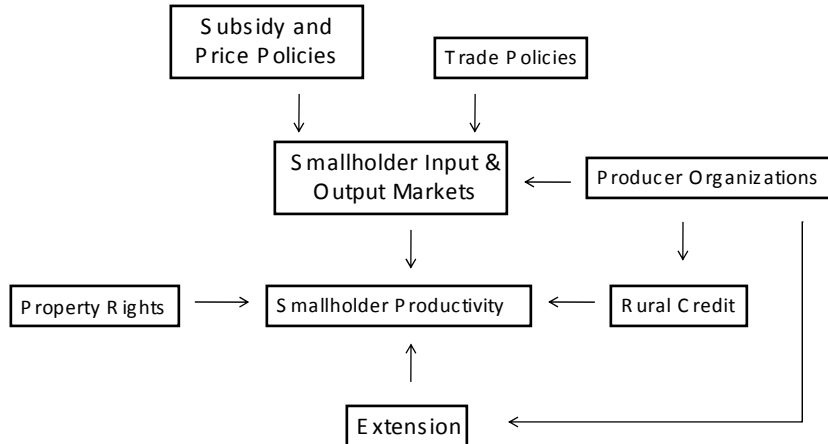
Globally, agricultural CH<sub>4</sub> and N<sub>2</sub>O emissions increased by 17% from 1990 to 2005, an average annual emission increase of 58 MtCO<sub>2</sub>-eq/yr. Both gases had about the same share of this increase. Three sources together explained 88% of the increase: biomass burning (N<sub>2</sub>O and CH<sub>4</sub>), enteric fermentation (CH<sub>4</sub>) and soil N<sub>2</sub>O emissions. (IPCC, 2007)

More sustainable land management focused on maintaining or improving environmental services and decreasing externalities, particularly associated with global warming, is now a central research thrust of the CGIAR. However, how to do this at the same time as increasing food production and agricultural productivity will be a central, ongoing challenge to 2050. The task is to seek complementary, “win-win” solutions, although recognizing that balancing trade-offs will be increasingly necessary and difficult. These

will require both technical solutions but even more critically policy, institutional and organizational innovations.

The other box that requires some further elaboration is that of policies and institutions and this area is developed in Figure 3. The central purpose of the policy and institutions area is to provide sufficient incentives for farmer investment in resource management, new technology, and assets, as well as to provide the institutional framework and services to support smallholder development and sustainable resource management. In more recent evaluations of why the Green Revolution was so successful in Asia and yet has to date been difficult to achieve in Africa, emphasis has shifted from a focus on just the technology to the disparity between the two continents in policies (Gabre-Madhin, Barrett, Dorosh, 2003) and institutions, particularly the efficiency of markets and the access to services (Poulton, Kydd, and Dorward, 2004). In essence, new technology is necessary but by no means sufficient to produce productivity gains in Africa of the type generated by the Green Revolution. Again, the CGIAR has over time come to recognize this need for complementary work in policies and institutions in support of the research on biological technologies, particularly in sub-Saharan Africa.

Figure 3: Framework for the Evaluation of Challenges in Policy and Institutions



Probably the most critical components essential to increases in smallholder productivity are efficient input and output markets that allow effective participation of poor producers and consumers. Well functioning markets are necessary to provide both the price incentives and the exchange outlets for smallholder production and yet high transaction costs in circumstances such as sub-Saharan Africa reinforce non-optimal, subsistence orientations of the rural poor and restrict effective pathways out of poverty. Moreover, efficient domestic markets are a necessary condition to compete effectively in international markets. International comparative advantage is as much due to low costs

of bulking, transport and marketing as it is due to production costs. Under such circumstances trade policy can be a second-best policy for agricultural growth, as compared to creation of more efficient domestic markets.

The other major issue in the area of policy and institutions is the cost-effective provision of services to smallholders. This is particularly the case for rural credit and agricultural advisory services. Financial sustainability of these services is a critical issue, especially in countries with very limited government budgets and yet large numbers of rural poor. This has led to attempts to privatize services that have previously been provided by the public sector, often attempting to transfer models developed in the urbanized economies of Latin America to the agrarian economies of Africa. There is significant debate as to whether institutional models can be transferred from one very different development context to another, or whether institutions need to evolve and organically develop within the contexts of individual countries and within the process of developing their own accountability relationships with their clientele.