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CONSULTATIVE GROUP ON INTERNATIONAL AGRICULTURAL RESEARCH

Interim SCIENCE COUNCIL

REPORT FROM THE iSC CHAIR

Interim SCIENCE COUNCIL SECRETARIAT

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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REPORT FROM THE iSC CHAIR

1. Introduction

This report from the iSC Chair brings the Group up-to-date on the Council's activities since AGM 2001, highlighting progress or accomplishments in the principal areas of iSC's responsibility: (a) assuring the relevance and quality of Centre science; (b) developing priorities and strategies, (c) commenting on resource allocations and monitoring programme implementation; (d) reviewing strategic considerations in the external environment, and (e) ensuring assessment of the CGIAR System's impact.

The activities of the iSC are structured in terms of the work of its three sub-committees – Standing Committee on External Reviews (SCOER), Standing Committee on Priorities and Strategies (SCOPAS), and Standing Panel on Impact Assessment (SPIA). These committees interact closely with one another given complementarities of their respective functions. The report which follows focuses on activities implemented by the iSC as a result of the work of SCOER, SCOPAS and SPIA which is supported by the iSC Secretariat located at FAO in Rome.

For activities that cut across the responsibilities of its sub-committees, the iSC employs *ad hoc* Working Groups, notably for the external reviews and analysis of Centres' medium-term plans and financing plans. In this case, the iSC Members serve in their capacity as Liaison Scientists for each of the 16 Centres, a function entailing broad responsibility in the areas of review, evaluation, and impact assessment that enhances The iSC's institutional memory vis-à-vis individual Centres' and their performance.

The Members of the iSC and the iSC Secretariat are listed in Annex 1. The iSC met twice during the reported period: iSC/TAC 82 during 7-12 April 2002 at CIP in Lima; and iSC/TAC 83 during 25-30 August 2002 at FAO and IPGRI, Rome. The iSC/TAC 82 Report has been distributed, and the iSC/TAC 83 End-of-Meeting Report is available at the AGM'02 for information.

Before turning to the Council's specific activities during the period under review, it may be noted that the iSC contributed to the work of the Working Group on Science Council (WGSC), set up by the Group to facilitate the transformation of TAC into a Science Council, in a number of ways. The iSC Chair, one iSC Member and the iSC Secretariat professional staff met for several hours with the WGSC at FAO, Rome on 17 May 2002. The iSC also prepared a document entitled "*Enhancing and Guarding the Relevance and Quality of Science in the CGIAR: An Operational Framework for the Science Council*" (SDR/iSC:IAR/02/07) for the WGSC to share its views on the proposed role and responsibilities of the future Science Council as endorsed by the Group at AGM'01. The iSC discussed the document at iSC/TAC 82 and envisioned the role of the Science Council as one of ***enhancing and guarding the relevance and quality of science in the CGIAR .*** In carrying out this role, the SC acts in a strategic advisory role in facilitating the implementations of the CGIAR vision and strategy, basing its advice on assessments, planning and evaluation activities. The

document is attached with this report as Annex 2. A summary version of the document was made available at the ExCo II in London, 16-17 April 2002.

During the period covered by this report, various iSC Members and iSC Secretariat staff attended meetings relevant to the work of the Committee. Usha Barwale Zahr in her capacity as Member attended the meetings of the CGIAR GRPC; Richard Harwood attended the INRM Workshop at Aleppo; Oumar Niangado the CORAF meeting; Hans Gregersen and Tim Kelley attended the CGIAR meeting on impact assessment of agricultural research and development in Costa Rica sponsored by CIMMYT and iSC/SPIA; Michael Cernea and Amir Kassam attended the CGIAR Social Research Conference at CIAT, Cali, sponsored by the iSC. The iSC Chair attended the CDC and CBC meetings in Rome and GFAR and EIARD meetings also in Rome. The iSC Chair Emil Javier and Shellemiah Keya attended the ExCo II and III in London and Washington.

2. The Activities of the Interim Science Council

These are described in this section under six headings, namely: (1) Assuring the Relevance and Quality of Science; (2) Developing Policy, Priorities and Strategies through Strategic Considerations in the External Environment; (3) Commenting on Centre 2003-2005 Medium Term Plans and 2003 Financing Plans; (4) Ensuring Assessment of the CGIAR System's Impact; and (5) Evaluation of Challenge Programmes.

2.1 Assuring the Relevance and Quality of Science

External reviews of Centres and Systemwide programmes and stripe reviews of themes which cut across Centre mandates have been a principal means by which TAC/iSC has carried out its responsibility to assure the quality and relevance of Centre science. The evolution in the modalities for carrying out research in the CGIAR, to include Challenge Programmes, in addition to Centre core research and Systemwide programmes, has influenced the iSC's agenda during the period under review. The iSC has been involved in the selection of CP candidates in the Pilot and the Regular processes. It has also considered the overall evaluation processes in the CGIAR and is presenting a paper to the Group. During the period under review, the following progress was made in the implementation or planning of reviews and in advancing other activities related to science quality and relevance:

2.1.1 External Programme and Management Reviews (EPMRs)

(a) Fifth EPMR of CIP

The Main phase of the Fifth EPMR of CIP was conducted from 25th February to 16th March 2002. The Panel comprised G. Edward Schuh (USA) (Chair), Alain Coleno (France), María Elena Cruz (Chile), Ricardo Godoy (USA), Karl Harmsen (The Netherlands), Jean-Yves Maillat (France), Wayne Powell (UK) and consultant John Griffith (Australia).

The EPMR Panel Report was considered at iSC/TAC 82 in April 2002 in the presence of the Panel Chair, Orlando Olcese representing the CIP Board, and the CIP DG Hubert Zanstra. The iSC prepared a commentary to the report endorsing largely the Panel's recommendations. The Review Report is on the Group's Agenda at AGM'02 in the Business Meeting under Agenda Item 3a.

(b) Fourth EPMR of ISNAR

The Main phase of the Fourth EPMR of ISNAR was conducted from 1st to 19th July 2002. The Panel comprised Dunstan Spencer (Sierra Leone) (Chair), Barbara Becker (Germany), Derek Byerlee, (Australia), John Griffith (Australia/USA), and consultant Fernando Bernardo (The Philippines).

The EPMR Panel Report was considered at iSC/TAC 83 in August 2002 in the presence of the Panel Chair, the Board Chair Moïse Mensah and the Director General of ISNAR Stein Bie. The iSC prepared a commentary to the report, suggesting further action for follow-up. The Review Report is on the Group's Agenda at AGM'02 in the Business Meeting under Agenda Item 3b.

(c) *Fifth EPMR of IPGRI*

The 5th EPMR of IPGRI is on schedule. The Initial Phase will take place from 25th to 29th November 2002 and the Main Phase from 3rd to 22nd March 2003, prior to the Centre Board meeting on 24-28 March. The review will be chaired by Dr Mike Gale (UK) from the John Innes Centre. The composition of the review Panel, including consultants, is as follows: Institutional issues (partnerships, networking, capacity strengthening, policies, conventions, access and benefit sharing, information, databases, IPR), Doris Capistrano (The Philippines) and John Mugabe (Kenya); Genetic resources conservation, characterisation and use, Bert Visser (The Netherlands); Governance and management, Paul Zuckerman (UK); INIBAP, Jorge Chang (Ecuador, consultant); System level issues, Carlos Correa (Argentina, consultant). Mike Gale and Paul Zuckerman attended IPGRI's full Board meeting in New Delhi from 30 September to 3 October, 2002. Field trips are being planned to regions of major importance for IPGRI's activities. The EPMR report will be submitted to the Science Council in March/April 2003, and to the Group at AGM'03

2.1.2 External Programme Reviews (EPRs)

(a) Fifth EPR of ICRISAT

The Fifth EPR of ICRISAT is planned for 2003. Paul Vlek (The Netherlands) from ZEF, Bonn, Germany, has been asked to serve as Chairperson in the review. A shortlist of candidates for the Panel has been prepared. The iSC plans to organize this external review in accordance with the new role and responsibilities of the future Science Council endorsed at AGM 2001 and discussed at ExCo II.. Thus, the review will focus on the relevance, quality and impact of ICRISAT's research programme including its alignment with the new CGIAR vision and strategy, and its management and Board oversight.

(b) CIMMYT, IFPRI and IRRI

The CIMMYT, IFPRI and IRRI EPRs are scheduled for 2003/2004. Discussions with the Directors General have not yet been initiated as these reviews will be commissioned and organised by the new Science Council.

2.1.3 Reviews of CGIAR Systemwide programmes

(a) First External Review of the Systemwide Programme on Integrated Pest Management (SP-IPM)

The Panel Report of the First External Review of the SP-IPM, carried out by Andrew Gutierrez (USA) (Chair) and Herman Waibel (Germany) in conjunction with the 5th EPMR of IITA, the Programme's Convening Centre, was considered at iSC/TAC 82 in the presence of the Panel Chair and Panel member via teleconference, and Peter Neuenschwander, SP-IPM Programme Leader and representative of the Convening Centre. The Review Report is on the Group's Agenda at AGM'02 in the Business Meeting under Agenda Item 3c.

(b) First External Review of the Systemwide Programme for Collective Action and Property Rights (SP-CAPRi)

The Panel Report of the First External Review of SP-CAPRi was considered at iSC/TAC 83 in the presence of the Panel Chair, John Bruce (USA), Per Pinstrup-Andersen, the Director General of IFPRI, the Convening Centre, and SP-CAPRi Programme Leader Ruth Meinzen-Dick. The Review Report is on the Group's Agenda at AGM'02 in the Business Meeting under Agenda Item 3c.

(c) Reviews of other Systemwide Programmes

The external review of the *Systemwide Programme of Alternatives to Slash and Burn* has been postponed till 2003 due to a funding shortage and problems in distribution of work with the Challenge Programmes and other reviews. Preliminary discussions have been held with ICRAF, the convening Centre of the programme. The implementation of this review and the external reviews of *Systemwide Programme on Participatory Research and Gender Analysis* (PRGA) and the CGIAR *Soil Water and Nutrient Management Programme* (SWNM), also initially scheduled for 2003, is subject to the SC's schedule of commitments and availability of funds form the iSC/SC budget. Unlike the EPMRs and EPRs, Systemwide reviews are financed from the iSC budget.

2.2.4 Stripe Review

(a) Capacity Strengthening in the CGIAR

The study on training is part of the stripe review and impact assessment of capacity strengthening activities in the CGIAR (See section 2.4, Ensuring Assessment of the CGIAR System's Impact: Training impact assessment). This study was commissioned by TAC in TAC 79 and is organised jointly by the Standing Committee on External Reviews and the Standing Panel on Impact Assessment. Currently the

desk study is being implemented. Collection and analysis of data and information from Centres has been completed. Key NARS stakeholders have been contacted in a Delphi survey to identify the most important issues that should be addressed during the Main phase. The methodology including scope and focus and the Terms of Reference for the main study panel are being designed by Leslie Cooksy, who has been assisting the iSC as consultant to this study.

2.1.5 Evaluation processes in the CGIAR

Comparative survey of internal and external reviews in other institutes: To learn for the purposes of establishing evaluation processes within the CGIAR, the iSC plans to conduct a survey of external review mechanisms in comparable institutions. The emphasis will be on reviewing institutes, projects and programmes with focus on evaluating science quality and relevance. Relevant institutions and persons will be contacted for drawing from experiences on best practices and evaluation practices promoted by professional associations.

Development of iSC/SC Roster of Scientists: There will be need for the Science Council to mobilize global expertise for drawing on global expert panels in the conduct of its strategic science and policy advisory activities and in different Centre, programme and thematic reviews and *ex ante* peer reviews. The current iSC expert roster includes some 2300 names. In the electronic database there are 530 CVs and a growing number of Internet references and new names are continuously added to the database. The CP peer review process and various other reviews have led to a meticulous search for experts – particularly from the developing regions. The TAC/iSC has accumulated confidential information about the performance of several of the experts in the roster.

The iSC is in the process of improving the organization, format and management of the electronic database to make it easy to manage and query for meeting the particular needs of the SC. The process will include a decision on the selection criteria and steps to be used for screening the overall roster, and designing an effective mechanism for screening and assessment. This will make the database a dynamic tool while minimising the effort needed for routine updating and management. In the future, the Centres could also draw from this expert information source through restricted Internet access.

2.2 Developing Policy, Priorities and Strategies through Strategic Considerations in the External Environment

Following completion of the CGIAR's new Vision and Strategy, TAC and then the iSC resumed its work on science policy, priorities and strategies through strategic considerations in the external environment likely to influence the System's future priorities and strategies and research portfolio. At AGM'01, TAC reported on its deliberations on emerging trends in science and their implications for the efficiency and effectiveness of the CGIAR in making progress towards its strategic objectives. The Committee explored trends in the biological, physical and social sciences as well as in policy and institutional analysis. The iSC has continued this

work and the highlights of the Council's activities during the past year include the following.

2.2.1 Planning System level priorities and strategies

At iSC/TAC 82, the Council discussed the concern that the CGIAR System needed an updated set of priorities and strategies based on the new CGIAR vision and strategy approved by the Group at ICW'00. It was becoming increasingly difficult to evaluate the CGIAR Research Agenda when the last time was in 1997 that the Group approved the revised System priorities and strategies against which MTPs for the period 1998-2000 had been certified by TAC. It was noted that although the role of the future Science Council (SC) was not yet clear in this area, the CGIAR System would need a norm for resource allocation which must be decided by what is considered as System priorities. It would appear that the SC will have three parallel functions: strategic planning, monitoring and evaluation, and impact assessment with feed back into planning. And, there will be a need for a common decentralized data base in the System for future strategic planning. It was highlighted that we needed to be in a state of readiness in case the SC would become responsible for providing a planning context and guidelines for System strategic plan to be prepared collectively by the Centres. In this regard it would be important to examine how other Systems similar to the CGIAR set priorities. The iSC endorsed the proposal to prepare guidelines for System strategic planning. This would require developing a new methodology for setting priorities in line with the new vision and strategy, and a new set of indicators.

2.2.2 Regional priority setting

At AGM 2001, TAC presented to the Group a *"Progress Report on Regional Approach to Research"* (SDR/TAC:IAR/01/32) which recorded progress achieved during 2001 in the implementation of Plank 4[1] of the new CGIAR vision and strategy endorsed at ICW 2000. The progress report highlighted the action taken by GFAR, regional and subregional organizations and CGIAR Centres to facilitate regional consultation processes to establish a regional approach to research priority setting and implementation for the CGIAR and NARS as envisaged by Plank 4.

The progress report also recorded the steps taken by TAC, in collaboration with GFAR, national and regional institutions and CGIAR Centres, to facilitate the implementation of the Group's decision at ICW'00 for piloting an experimental bottom-up, priority setting approach in the Central America sub-region. In support of the regional approach to research, TAC either prepared or commissioned the preparation of several documents during 2001 and shared them with the Group at MTM 2001 and AGM 2001.

The iSC has provided a second *"Progress Report on Regional Approach to Research"* (SDR/iSC:IAR/02/27) for consideration at the AGM'02 Stakeholder Meeting under the Agenda Item 6a (Updates, Regional Priority Setting). This progress report records the action taken by TAC/iSC and developments since AGM 2001 in

[1] Plank 4 of the new CGIAR vision and strategy calls for the adoption, in collaboration with national and regional partners, of a regional approach to research planning, priority setting and implementation.

further facilitating the regional approach to research in the CGIAR. It also summarizes the progress in 2001.

Since AGM 2001, TAC and then the iSC focussed its efforts in facilitating the regional consultation process in sub-Saharan Africa region, while keeping a watching brief on regional consultation activities in the other regions. In particular, as a contribution to the consultation process in the West and Central Africa subregion, and in collaboration with GFAR and CORAF, the iSC commissioned two studies to examine the causes of low impact of agricultural research in the subregion and possible solutions leading to improved future performance, from two perspectives – national and international. Two consultants were hired to work with the iSC Standing Committee on Priorities and Strategies (SCOPAS) to conduct the studies. SCOPAS provided the terms of reference for the studies. Willem Stoop examined the agricultural research performance from a national perspective and Lukas Brader from an international perspective. Syngenta Foundation provided support to the Mali portion of Willem Stoop's work.

Willem Stoop's report is entitled *"A study and comprehensive analysis of the causes for low adoption rates of agricultural research results in West and Central Africa: possible solutions leading to greater future impacts: The Mali and Guinea case studies"* (SDR/iSC:IAR/02/21). Lukas Brader's report is entitled *"A Study about the Causes for Low Adoption Rates of Agriculture Research Results in West and Central Africa: Possible Solutions Leading to Greater Future Impacts"* (SDR/iSC:IAR/02/22)

The two reports were discussed at iSC/TAC 83 in August 2002. The iSC believes that these studies should be given maximum visibility as they bring new ideas to a problem still in great need of good diagnostics and new approaches. They will also be useful in providing guidelines in defining CPs for sub-Saharan Africa. Therefore, the iSC requested SCOPAS to prepare a commentary on the two reports, which is presented in the iSC's second *"Progress Report on Regional Approach to Research"* (SDR/iSC:IAR/02/27), on the agenda at the AGM'02 Stakeholders Meeting, together with the full reports as annexes..

In conclusion, it needs to be noted that the lack of CGIAR support to the pilot experiment in Central America has led to a loss in momentum and enthusiasm from the regional and sub-regional organizations in organizing and engaging in multi-stakeholder consultation processes for research priority setting. However, planning activities of the various Challenge Programmes have provided some impetus to the process of integrating regional priorities with CGIAR priorities. This integration process could be strengthened and sustained if one regionally driven Challenge Programme initiative from the current batch of CPs in the regular process is supported by the CGIAR. There is evidence that some CGIAR donors would be willing to provide support to competitive research with a regional perspective which would facilitate the implementation of Plank 4.

In this regard, continuing effort will be required by the CGIAR Centres, GFAR, and the regional and subregional organizations to strengthen and sustain multi-stakeholder planning and priority setting processes at subregional levels. Regional research priorities for international public goods research should be of

interest to CGIAR and its regional partners for collaborative research. It would be important for the CGIAR to provide support to such collaborative research, particularly where regional partners are willing to contribute resources and willing to develop multi-stakeholder planning activities involving the farmers, the private sector and the development and investment agencies. Systemwide and Challenge Programmes are effective mechanisms to promote the integration of regional priorities with CGIAR priorities for international public goods research.

Studies such as those by Willem Stoop and Lukas Brader should prove to be very useful for regional priority setting, and have indeed already been discussed by CORAF. They provide a sound basis for improving agricultural research planning and implementation. The iSC suggests that such studies need to be conducted by the Centres in collaboration with their regional and subregional partners in all subregions so as to improve the relevance, quality and impact of agricultural research.

The future Science Council should continue to commission such studies for other subregions, particularly for Eastern and Southern Africa, South Asia and the Andean sub-region. In each case, these studies should be prepared by people with considerable knowledge of the subregion/region and also great familiarity with the way the CGIAR works. The Stoop-Brader studies have shown clearly that there is a need for better ways of assessing impact of agricultural research. Centres and their NARS partners are in a unique position to be able to monitor the impact process in a disaggregated fashion so that the CGIAR is able to obtain a more accurate picture of what is working and what is not. The future Science Council should facilitate the development and implementation of such methods.

2.2.3 Poverty related studies

The CGIAR has many years of accumulated experience in using agricultural technology to seek an impact on poverty reduction. In order to take advantage of this accumulated knowledge in providing guidelines for future investments, TAC requested IFPRI at MTM2000 to prepare a study report of the links between CGIAR research and poverty reduction. The study report together with a TAC commentary was made available to the Group at AGM 2001 in the context of its deliberations on the regional priority setting under the Agenda Item 5c (Updates, Regional Priority Setting) of the AGM'01 Stakeholder Meeting. The IFPRI study is an important document that will serve as a benchmark in pursuing further studies of the technology-poverty nexus at the regional level for sometime to come.

The understanding of the nature of the linkages between poverty and technology has important relevance to the CGIAR priority setting process, and to the regional priority setting activities that are underway in all the regions in the context of the new CGIAR vision and strategy. TAC considers that it is important to rigorously establish causal linkages before firm conclusions can be offered about the understanding of the technology-poverty linkage in the different regional settings. In this regard TAC has requested IFPRI to develop case studies on the technology-poverty relation which, when completed, will enrich our current knowledge and be made available to the CGIAR Stakeholders. Also, further work on technology-poverty relationship is being planned utilizing formal modelling.

2.2.4 Poverty mapping

Progress report on poverty mapping in the CGIAR was discussed at iSC/TAC 82 and 83. The iSC requested the CGIAR's Consortium for Spatial Information (CSI) to provide updates on its activities, particularly the involvement of CGIAR Centres in the FAO-coordinated multi-institutional (CGIAR/TAC-FAO-UNDP-GRID-ARENDAL) Global Poverty Mapping Project. This project is supported by a grant from the Government of Norway. The iSC considers the use of GIS tools for poverty mapping and poverty analysis a very important initiative, not only as a research tool but also to improve decision-making by Centres and the iSC in allocating resources to research in seeking a maximum poverty reduction impact. The CSI provided two updates to the iSC (SDR/iSC:IAR/02/12 and SDR/iSC:IAR/02/25) which shows that seven CGIAR Centres are now participating in the Global Poverty Mapping Project.

2.2.5 Integrated natural resources management (INRM)

TAC's evolving position on INRM was summarized in the TAC Chair's report to AGM 2001. During 2001, TAC prepared two documents: "*Evolution of NRM Concepts and Activities in the CGIAR*" (SDR/TAC:IAR/01/18), is a comprehensive summary of pre-1996 CGIAR activity in NRM, the TAC study on priorities and strategies for soil and water research in the CGIAR, recent thinking and activities related to NRM, and TAC's currently evolving perspective on INRM in the CGIAR; and "*NRM Research in the CGIAR: A Framework for Programme Design and Evaluation*" (SDR/TAC:IAR/01/24 Rev.1) which elaborated TAC's and iSC's forward-looking ideas on CGIAR priorities and strategies in INRM and proposes a framework for programme design and evaluation. These documents were distributed to the CGIAR Stakeholders at AGM''01.

At iSC/TAC 82 and 83, the Council discussed and agreed to prepare, in collaboration with the CGIAR Task Force on INRM, a document of INRM case studies which would illustrate a set of successful INRM research cases. The cases would highlight the underlying INRM principles and how these were operationalized in addressing NR problems in the context of CGIAR gaols. Excellent expression of interest has been registered by the CGIAR Centres.

2.2.6 Water management

TAC's evolving position on water management research in the CGIAR was elaborated in the TAC Chair's report to AGM'01. The Group was informed that during 2001, TAC had prepared, with the CGIAR Centres, an overall CGIAR strategy document on water management research entitled, *Water and the CGIAR: A Discussion Paper* (SDR/TAC:IAR/01/23A). At iSC/TAC 82, the Council discussed a revised version of this document which incorporated comments and input from Centres. The paper was prepared with three objectives in mind; first, to inform CGIAR stakeholders of the current state of water in the context of CGIAR activities and of the needs, challenges and opportunities for water research in the CGIAR. A second objective was to identify the most relevant issues and goals to be pursued in research by the CGIAR, given the complexity of water problems, the probable future scenarios, and the comparative advantages of CGIAR Centres. Finally, a vision for the

future and the elements of a research agenda on water for the CGIAR, including possible roles of the various Centres in this area, are presented.

The overall aim of the paper was to facilitate discussions towards the formulation of a common strategy for water research in the context of the evolving CGIAR framework for integrated natural resources management. Based on the discussion at iSC/TAC 82, the document was revised once more and endorsed at iSC/TAC 83. A copy of the document SDR/TAC:IAR/01/23A Rev. 3 is attached with this report as Annex 3 for information and comments from CGIAR Stakeholders. The iSC is pleased to inform the Group that the research framework for water management proposed in the document was adopted by the proponents of the Challenge Programme on Water and Food.

2.2.7 Social research capacity in the CGIAR

At the behest of TAC, a CGIAR Conference on Social Research was held at CIAT from 10-13 September 2002. The proposal for the need for such a Conference was originally prepared by Michael Cernea in a document entitled, "*Social Science in the CGIAR: Supporting the Strategy—Achieving Impact"* (SDR/TAC:IAR/01/25). A conference organizing committee led by CIAT planned and implemented the proposal. The iSC commends CIAT and the Conference Organizing Committee for their effort.

The Conference was preceded by: (a) a stripe survey of Centres to establish baseline information on the current social science capacity in the CGIAR; and (b) a review of TAC-commissioned external reviews since 1995 in terms of what the review panels and TAC discussed and recommended with regards to social science research. The results are available on the Conference website.

The iSC provided support to the Conference, and Michael Cernea and Amir Kassam attended. They contributed the following papers respectively: (a) *The Institutionalization of Social Research within the International Agricultural Research System -- A message from the Science Council and some personal observations; (b) An Overview of Social Science Research in the CGIAR.*

A formal report of the Conference is expected to be available to the Group at AGM'01. A brief note prepared by Michael Cernea and Amir Kassam is attached as Annex 4. The Conference focused its attention on the need for greater social and sociocultural research capacity in the CGIAR, given the new impact oriented Vision and Strategy and the increasing demand and need for participatory research for technological, social and institutional innovations and policy formulation. The Conference highlighted a need to raise the status and capacity of social research in the CGIAR to ensure that research and products are environmentally as well as socially sound based on an effective integration of biophysical and social sciences at all stages of technological research process in the CGIAR. The iSC considers that any recommendation to increase resources directed towards social research would need to be evaluated in the context of new CGIAR priorities and research opportunities.

2.2.8 Food safety

Based on the TAC *Proposal to Review Food Safety Considerations in CGIAR Research* (SDR/TAC:IAR/01/21A), TAC decided that a "Think Piece" on food safety should be commissioned for consideration by the iSC. The document should describe the food safety problems and issues and the research and development implications. The study document should focus on the particular concerns and needs of the poor in the developing world. FAO agreed to prepare a Think Piece in collaboration with WHO, and a progress report was presented by FAO at iSC/TAC 83. It is proposed by iSC that based on the final version of the Think Piece and further discussion about what are the relevant issues for the CGIAR, the future Science Council should commission, if deemed necessary, the preparation of a strategic framework paper through a panel of experts. The Paper would assess priority research needs and opportunities for the CGIAR in the context of its new vision and strategy, and serve as a framework for addressing food safety concerns for the poor in technology and policy research and in capacity strengthening.

2.2.9 Biosafety

The iSC is under obligation to conduct an independent study on biosafety as called for by the Group at Durban. It is the scientific issues related to gene technology applications that will inform policy and regulatory instruments. The iSC therefore aims to clear up such scientific issues in meeting the expectations of the Group. The iSC/TAC 82 considered a revised study proposal prepared by Gabrielle Persley (Consultant) entitled *"Proposed Study on the Safe Use of Gene Technology and Its Products"* (SDR/iSC:IAR/02/13 Rev.1). Gabrielle Parsley is serving as Scientific Secretary to the Panel of experts which will carry out a strategic study. The Panel Chair is Brian Johnson (UK), Head of Agricultural Technology Group, English Nature. The study objectives are to: (1) Identify the issues in the safe use of gene technology and its products that are relevant to the Mission, research activities, and partnerships of the CGIAR. (2) Develop principles and practice to guide the CGIAR and the Centres in the safe use of biotechnology, based on current principles and best practices and emerging trends in science and public policy. (3) Advise on how the CGIAR System can continue to monitor developments in these fast changing fields and have in place mechanisms (including the necessary institutional strengths) to ensure that the principles and practices of the Centres and their partners reflect current best practices and timely responses to emerging issues.

The suggested case studies include: *Biodiversity issue:* Gene flow from transgenic crops in Centres of crop diversity, including any potential impact on the CGIAR gene banks; *Biotic stress:* Bt maize for release in Mexico and Kenya; *Abiotic stress*: Salt tolerant barley for North Africa and West Asia; *Livestock diseases*: New vaccine for East Coast Fever in cattle in Africa, in relation to the production and gene-based delivery of a new vaccine; and *Fish:* Transgenic fish for release in Asia and Africa; Information for the case studies, which will also include vegetatively propagated crops, would come from the interested Centres and CDC has been approached to collaborate in this initiative.

2.2.10 Ethics and Science in the CGIAR

The iSC/TAC 82 considered a pre-proposal paper *"Ethics and the CGIAR"* (SDR/iSC: IAR/02/15) by Amir Kassam and Elena Moreddu which proposed the following objectives for a study called for by the Group at Durban: (1) Assess the present CGIAR policies and the policies and practices of the CGIAR Centres with regard to ethics. (2) Identify the issues in ethics that are relevant to the Mission, research activities, and partnerships of the CGIAR. (3) Develop principles of conduct to guide the Centres in the safe and ethical use of science, based on current principles and practices and emerging trends, and in the development and dissemination of its products. (4) Make recommendations on a possible future ethical framework of policies and guiding principles of conduct for the CGIAR scientific activities, products and expected outcomes which may form the basis for a Code of Ethics for the CGIAR-supported Centres. This should include advice on how the CGIAR System can continue to monitor developments in ethics and have in place mechanisms (including the necessary institutional strengths) to ensure that the ethical principles and practices of the Centres reflect current best practices and timely responses to emerging issues.

Given the diversity of human cultures and value systems, the rapid advances in science and technology, the particular goals and focus of the CGIAR, it is important that the ethical values and principles that guides the CGIAR and the conduct of all its research are explicitly reflected upon and described. Ethical issues and integration of ethical consideration into CGIAR's work apply not only to the development of GMOs but to a wide range of other aspects of the CGIAR research agenda such as genetic resources, water management, animal and fish production, forest management, the environment, the way research relevance and quality is sought and sustained, the manner by which research products and information are made accessible and shared, the relationships with partners, farming communities and other stakeholders; etc. etc.

Efforts in the CGIAR have so far focussed mainly on ethical issues surrounding the conservation, use and enhancement of genetic resources. The Genetic Resources Policy Committee sponsored a workshop on *Ethics and Equity* in 1997, which focused on ethical dimensions, related to genetic resources conservation and use. This led to the adoption of the *CGIAR Statement of Ethical Principles Relating to Genetic Resources"* in 1998. As a result, the CGIAR Centres were encouraged to set up ethics committees to formulate ethical principles and oversee the implementation of these principles with regards to genetic resources. There have been CDC statements on GMOs and IPR that touch upon ethical considerations.

In carrying out the study, it was considered important to examine how other organizations have handled ethical issues and focus on issues which are high on the agenda but relevant to the CGIAR. It was agreed that an issues paper would be an appropriate way to prepare the way forward for a full strategic study which would lead to a document the Group expects from the Science Council. Arrangements are being made for a Consultant experienced in the ethics of science to prepare a broad-based discussion paper on issues relevant to the CGIAR. The paper would delineate the scope of the study that could be implemented through the proposed panel which would recommend a possible future ethical framework of policies and guiding

principles of conduct for all CGIAR scientific activities, products and expected outcomes.

2.2.11 International public goods in an era of IPR

The iSC/TAC 83 discussed further the revised proposal prepared by Alain de Janvry and entitled "*What strategies for the CGIAR to conduct research and deliver technological innovations that benefit the poor in a context of intellectual property rights?"* (SDR/TAC:IAR/01/28 Rev.1). The proposal called for iSC/TAC sponsored survey of practices in the CGIAR and two papers as follows, followed by a workshop sponsored by ISNAR.

(i) *Survey* of practices followed by CGIAR scientists to secure the freedom to innovate and to operate needed to achieve the CGIAR's mandate.

This will result in developing a typology of approaches, and in analysing concrete experiences of use of each approach by the CGIAR or their downstream clients to secure these two objectives.

(ii) Development of *IP mechanisms* to access information on property rights and accessibility.

This will include a review of the IP informatics and IP exchange sites that are currently operating.

The recent proposal of developing an *IP clearinghouse* for agricultural biotechnology will be analysed and the potential role of the CGIAR in the development and/or use of this mechanism will be explored. The clearinghouse would serve to both facilitate identification of intellectual property claims and to make the market for proprietary technology work (price setting, contracts, and conflict resolution mechanisms).

(iii) Development of mechanisms to transfer innovations to *intermediaries* to secure sustainable benefits for the poor.

This is important not only for the more traditional activities of the CGIAR, namely research on seeds and agricultural technologies, but also for the emerging activities in the field of NRM research. Intermediaries differ markedly for the two types of products. Securing the protection of ideas and their use for CGIAR poverty and environmental objectives requires developing best practice knowledge on how to proceed.

It was reported that communication had been established with ISNAR and there was a possibility that ISNAR could prepare a background paper on practices in the CGIAR and how scientists are handling IPR issues in relation to research and research products. However, it was felt that it would be useful to also ask groups outside the CGIAR, e.g., ISAAA on the help needed by the developing country NARS obtain access to proprietary products; and the Rockefeller Foundation on developing an IP clearing house, and possibly on the interactions between US Land Grant Colleges and African NARS. The three background papers could all be brought

together for discussion first in the iSC/TAC and then at a small workshop at ISNAR. The iSC endorsed the proposal for a survey document from ISNAR by CAS and two papers from the outside groups ISAAA and RF. SCOPAS was requested to prepare the ToRs for the survey document and for the external papers**.** The iSC suggests that the future Science Council should consider implementing this proposal.

2.2.12 Abiotic Stress genomics

At TAC 81, the Committee requested SCOPAS to organize a discussion paper on crop abiotic stress genomics to be prepared with the help of a consultant in consultation with CGIAR Centres for consideration at the next meeting. The basis for this was that difficult environments were beset by abiotic stresses and CGIAR has not made a significant difference in such environments. Mike Gale from John Innes Centre was hired to prepare a discussion paper on what molecular biology and abiotic stress genomics may have to offer to genetic enhancement and crop improvement, with a focus on relative importance of abiotic stresses; what CGIAR community is doing about it; assess NARS capacity; and how to coordinate the effort in the CGIAR. Mike Gale presented his paper *"The potential application of molecular biology to genetically enhance crop tolerance to abiotic stress: a discussion document"* (SDR/iSC:IAR/02/10 Rev.1) in a videoconference mode at iSC/TAC 82. The report is presented in Annex 5.

Mike Gale report shows that the significance of abiotic stress has not been lost on CGIAR scientists and there is considerable work aimed at stress tolerant crop improvement already going ahead. Together with NARS and ARIs, the Centres are working towards an understanding of the genetic and physiological control of tolerance to the key stresses in their regions for their mandate crops, and are applying the results in breeding programmes. Progress, although incremental, is real and demonstrates that the problem is tractable to the genetics approach. In short, breeding is a viable option.

However developments elsewhere tell us that the future will not be the same as the past. One such area is genetics where a new science is emerging from the masses of DNA sequence and the associated novel and high throughput technologies. The new genomics promises more rapid and more spectacular returns, but at a cost. Some of these massively parallel genomics and gene manipulation technologies are already being turned on the abiotic stress tolerance problem, with some success - albeit at present in 'model' organisms and by ARIs in developed countries. Some Centres are already tooling-up for plant genomics research. Another development is the discovery of 'synteny' where genome organisation has been found to be much more conserved over species than was previously thought. Application of synteny will allow advances in our knowledge about stress tolerance and the underlying genetics to be transferred between crop species. Synteny will similarly allow CGIAR and NARS scientist's access to the array of genomics resources already available for arabidopsis and rice, which are emerging as models for broad-leafed and cereal crop species.

It is possible for CGIAR scientists to harness synteny and the new genomics for improvement of their own mandate crop species. However, in order to do so in a cost-effective and efficient manner it may be necessary to develop new ways of doing science. These will involve more rationalisation and centralisation and sharing of

rapidly improving technologies; more outsourcing to providers of standard scientific services; the assembly of multidisciplinary teams and networks in virtual Centres that will facilitate the sharing of information between crops and collaborators. DNA-based science, and the expensive equipment it begs, is identical for all organisms. Suddenly there is obvious potential for economies of scale in major collaborations.

The time could be right for a full-blooded assault on abiotic stress. Ongoing work shows that the motivation is already there. The question is not whether the work is needed, rather only when, how and what firepower should be brought to bear. A really effective collaboration will involve the NARS with their germplasm collections, their knowledge of and access to stressed agricultural environments, and their plant breeders, ARIs with their experience of technology and model systems, the CGIAR Centres with their comparative advantage with the mandate crops, their collections and their networks to the developing world, and possibly industry as well.

The report describes some of the successes from cross breeding and biotechnological approaches to an improved understanding of stress tolerance and improved varieties. The report outlines some of the potential of the new science, and discussed the diverse skills that will be needed for ultimate success and the possible roles to be played by the several partners. The report also hints at a new way of working with more generic technologies and a more generic science, which will be applicable to all future crop improvement programmes in the developing world. The report offers possible options that could be considered for organizing abiotic stress genomics research in the CGIAR.

The iSC is pleased to note that a number of ideas that are proposed in the document by Mike Gale were considered by the proponents of the Challenge Programme on Unlocking Genetic Diversity in Crops for the Resource Poor which has a focus on abiotic stress.

2.2.13 Information and communications technology

At iSC/TAC 82, the Council discussed the paper "*ICT and the CGIAR"* **(**SDR/iSC:IAR/02/14) prepared by Amir Kassam and Saurav Barat. CGIAR is in the business of generating and disseminating information and knowledge. ICTs essentially provide the power to access, store, maintain, increase, process, transform, adapt, transmit and disseminate information and knowledge. ICT provides connectivity for communication, networking, accessing and sharing information, and partnership and cooperation. Thus, ICTs are essential tools in research and research support, extension and training just as they are in all other aspects of agricultural and national development including planning and administration, farming and other productive and service sectors, input supply and output delivery, markets, etc. ICTs are tools and mechanisms to facilitate CGIAR's main business. However, the CGIAR cannot be into ICTs as a main thrust anywhere. There are other organizations that are better at that.

For CGIAR research and related activities, opportunities for advances in ICTs can be analysed in terms of their role in:

(i) Research input – basic spatially organized information on poverty, natural resources and agro ecosystems, community etc., characterization, mapping and spatial analysis, diagnosis, planning and priority setting, *ex-ante* assessments, etc;
(ii) Research process – tools and methodologies, multi-scale Research and analysis; *ex-ante* assessments;
(iii) Research outputs and outcomes - data, information, knowledge and know how, tools, models, policy options, techniques and technologies, dissemination, adoption, *ex-post* assessments, etc.;
(iv) Research support – library and documentation services, computer facilities, research data and records management, etc.;
(v) Capacity building activities within Centres and with national partners;
(vi) Communication, research collaboration and partnership;
(vii) Farming and community practices – precision farming, response farming, common action and property management.

The paper looked at ICT in relation to the CGIAR vision and strategy and examines the use of GIS-based ICTs in the CGIAR which are applied to organize, store and retrieve, increase, process and disseminate spatial information. It also provides a short summary of ICTs used by CGIAR Centres for access and dissemination of information from their research and related activities.

The paper proposed two follow up actions. (1) A full discussion paper be prepared on the opportunities arising from advances in ICT in terms of: research inputs; research methodologies and processes; research outputs, delivery and outcomes; research support; communication, research collaboration and partnership; and as an activity to strengthen capacity of national partners. (2) The Coordinator of the Consortium for Spatial Information at CIAT to organize the preparation of a CSI discussion paper on the opportunities and potential for GIS-based ICTs in contributing to CGIAR goals and research at the global and regional levels.

There is a CDC sub-committee on ICT and a number of Centres are involved in strengthening developing institutions. ISNAR has four experts working on aspects dealing with ICT training and distance learning; construction of websites; building e-networks in collaboration with SROs; and ICT policies and resources in NARS. The iSC decided that it would be useful to bring together for iSC discussion the experience of ISNAR and other Centres in the area which deals with the relationship of CGIAR with the outside world, particularly NARS, and the opportunities offered by advances in ICT. Similarly, for ICT opportunities within the CGIAR, it decided that a discussion paper on opportunities offered for research by GIS-based ICT would be appropriate. This could be followed by discussion papers on other ICTs for NRM and genomics research.

The iSC agreed that an overview discussion paper on CGIAR relationship with NARS in information exchange and access, networking and institution strengthening would be useful, and ISNAR could coordinate the preparation of such an inter-Centre paper. The iSC agreed that a discussion paper on GIS-based ICT for scientific

research within the CGIAR be prepared and CSI could coordinate the preparation of this paper. It was agreed to consult CDC before formally approaching ISNAR and CSI. CDC was consulted in May 2002 and assignments have been accepted by ISNAR and CSI to prepare the above discussion papers for consideration by the future Science Council.

2.2.14 Animal and Fish Genetic Resources

At iSC/TAC 82, the Council argued that there was a need to prepare two strategic concept notes in consultation with FAO and the concerned Centres on animal and fish genetic resources, particularly on what the world is doing about it, and what the CGIAR is doing about it. The iSC requested SCOPAS to organize the preparation of two concept notes, one on animal genetic resources and the other on fish genetic resources for discussion by the iSC. CDC has been informed about the iSC's interest in this area, and the work will be done in consultation with FAO and the CGIAR Centres. The iSC suggests that this be followed up by the future Science Council.

2.2.15 The Reported Contamination of Maize landraces through introgression of transgenes in Mexico

Usha Barwale Zehr who represents the iSC in the GRPC reported on developments in GRPC including the insistent alleged contamination with transgenic materials of maize landraces in Mexico and in the CIMMYT gene bank. She stated that confirmatory test run by responsible Mexican authorities showed that the scientific data of the alleged contamination were flawed. The iSC concluded that GRPC and CIMMYT are on top of the situation. The iSC will keep a watching brief on the issue.

2.3 Commenting on Centre 2003-2005 Medium Term Plans and 2003 Financing Plans

The iSC assessed in a virtual mode the programmatic implications of the plans of the 16 Centres with a view to reporting to the Group at AGM 2002 on the CGIAR's 2003 Research Agenda, and the programmatic implications of any significant potential financing gaps or deviations. The iSC's focus was on changes from existing plans, particularly those responsive to the Vision and Strategy approved by the Group at ICW 2000. As before, within this broad frame of reference, the iSC's analysis employed the following criteria: scientific priorities and focus of the overall research portfolio or of major projects within it; the research content of the portfolio as reflected by significant restructuring or addition/phasing out of projects; linkages and partnerships with other institutions involved in research and development; and responsiveness to major recommendations of TAC-commissioned external reviews.

Details of the iSC's views on each of the 16 Centre MTPs and recommendations are reported to the Group under AGM'02 Business Meeting Agenda Item 5a (CGIAR Financing Plans) for which the iSC has prepared a document entitled *"iSC Comments on Centre 2003-2005 Medium Term Plans and 2003 Financing Plans"* (SDR/iSC:IAR/02/26). The document presents a short commentary on each Centre, highlighting the programmatic implications, if any, of their respective

2003-2005 MTPs. It provides a brief overview of the most significant programmatic developments in the 2003 Research Agenda at Centre and System levels, highlighting implications of the proposed MTPs and financing plans on the overall resource allocations trends. It also highlights inter-Centre efforts in strategic areas that have programmatic and resource implications. The iSC makes two recommendations to the Group regarding the future evaluation of the Research Agenda.

2.3.1 2003 Research Agenda

The iSC notes that the MTPs of most Centres are broadly consistent with the Group-endorsed Plans. Centres' project portfolios have been maintained except in the case of ICRISAT, IFPRI and IITA. Also, IWMI, CIFOR, ISNAR and ILRI are in the process of making significant changes to their research agenda. The iSC finds that these changes permit the seven Centres to respond more effectively to the directions of the new CGIAR Vision and Strategy.

Specifically, the consolidation of ICRISAT's agenda will permit that Centre to strengthen its impact assessment work and also respond to the particular needs in South Asia and sub-Saharan Africa, emphasising a thematic and biotechnological approach to crop improvement involving public and private sector partners. In addition, there is renewed emphasis on the importance of soil fertility, water constraint and seed supply system in SAT agriculture. The rationalization and expansion of IFPRI's project portfolio conforms to that Centre's mandate. New activities are foreseen in areas dealing with: institutions for market development, Diet Quality and Change; Nutrition Policy Process; Pathways from Poverty; and Strategic Alliances and Networks for Policy Impact. The restructuring and consolidation of IITA's portfolio is consistent with the need to strengthen the agro ecological approach and to simplify project and management structures within the Centre. It emphasizes demand and impact driven activities through a food system approach to ensure responsiveness to changing demand from the rural, urban and expanding commercial sectors, and targeted towards improvements in rural livelihoods.

MTPs of IWMI, CIFOR, ISNAR and ILRI show strategic modification being made to their research agendas in line with the new CGIAR Strategy. IWMI's MTP continues to give positive impetus to an integrated water resources management focus, while permitting integration of the land dimension of water management into the Centre's research agenda. Through Systemwide Programmes, IWMI also is strengthening research on the health impacts of water management and on water productivity. CIFOR's consolidated project portfolio is directed strongly towards a livelihood/poverty-oriented agenda, including a greater emphasis on ecosystems services of forests and mixed forestry systems which support large numbers of poor people. ISNAR's MTP focuses on identifying institutional arrangements that promote more effective generation and use of new knowledge for achieving the goals of poverty alleviation and food security. This will provide a positive impetus to regional and sub-regional organizations in their work to adapt ISNAR's products for national applications. This will be aided by the increased emphases given by the MTP to decentralisation of activities provided critical mass can be sustained in support of such activities. Finally, ILRI's MTP provides information of its emerging revised agenda which is based on a conceptual framework in which pathways out of poverty are

identified and linked to the strategic research themes which provide a sharper focus on poverty alleviation and livelihood improvements.

A key achievement by all Centres has been the additional efforts that have gone into establishing closer planning consultations with regional and subregional research organizations (ROs/SROs), NARS, civil society, regional financial and development assistance community. This is providing the impetus to establish effective processes to integrate regional and global priorities into concrete programmes. The iSC commends the remarkable goodwill and effort that has been extended by the ROs/SROs and NARS to the CGIAR Centres in attempting to establish a regional approach to research. Benefits from such regional planning consultations are already visible in several of the proposed Challenge Programmes.

All Centres now present their projects, including Systemwide Programmes, in logframe format, with a detailed listing of goals, objectives, outputs, milestones, verifiable indicators, and assumptions. The fact that the Centres are now using this approach makes the research planning process more transparent and facilitates monitoring of implementations. These factors, in turn, enhance Centres' accountability for the timely delivery of outputs, a necessary condition for achieving impact. Taken together at the System level, the MTPs reflect continuity in the aggregate allocation of resources to the 5 Logframe Outputs comprising the CGIAR's Research Agenda (see Section 3.2 on resource allocation trends). The iSC observes a number of trends in specific activities that are of strategic significance. These are noted briefly further below under each logframe output.

Germplasm Collection, Characterization and Conservation:

The International Treaty on Plant Genetic Resources for Food and Agriculture (IT), adopted end 2001, was a crucially important development for the CGIAR as the major in-trust holder of the international genetic resources in its *ex situ* collections. The Centres will individually sign agreements with the Governing Body of the Treaty. The IT will have implications in the management of genetic resources by the Centres and the related intellectual property. The iSC notes that unfortunately some crops relevant to the CGIAR were omitted from the list of species included in the multilateral system of access and benefit sharing, namely groundnut, soybean, some forage species and wild crop relatives. A development complementary to the IT will be the establishment of the Global Conservation Trust, for which IPGRI has led a major campaign to mobilize donors' funding commitment. The iSC emphasizes the importance of this long-term financing strategy in bringing sustainability to the maintenance of genebanks within and outside the CGIAR and in increasing the opportunities for evaluating and utilizing the genetic resources more effectively for improving crop productivity.

The iSC considers the Challenge Programme (CP) on unlocking genetic diversity in crops for the resource poor is an important programme with significant potential for economies of scale and synergy among the CGIAR Centres and their research partners. The main benefit in this initiative would come through capitalizing on the genetic value in the germplasm collections, which through the means of molecular science and bioinformatics can be defined more precisely and fully. The iSC hopes that the proposal can be further developed and ultimately launched as a CP.

The iSC is pleased to note that the formulation of the CP benefited from the strategic deliberations of the CGIAR Working Group or Task Force on Genomics convened by IRRI. The iSC believes that the Task Force on Genomics is beginning to provide the new impetus needed to more efficiently organize CGIAR's work in the priority areas of genomics research and bioinformatics for crop improvement.

Germplasm Improvement:

In the research agenda of the commodity Centres genetic improvement has maintained a steady share of resources. The iSC notes, however, a one percent point drop in the share projections for 2003-2005 compared to the actual 18% share in 2001 of the total CGIAR resources.

The iSC recommended two CPs focusing on germplasm improvement to be considered by ExCo. As discussed above, ExCo decided not to recommend to the Group the CP proposal on genetic resources in its current form. In supporting the further development of this CP proposal, the iSC repeats the message of TAC in its commentary on the 2002-2004 MTPs, in which TAC expressed its support to concerted efforts in functional genomics for advancing the breeding of crops and traits that are important for the poor. Centres are increasingly tapping into the new advances in molecular biology including genomics research. Other areas of emphasis in germplasm improvement include biodiversity and post-harvest research.

The iSC is pleased to see that the CP on biofortification is very likely to be endorsed at AGM. Several Centres will have a chance to participate in this CP which has direct relevance to their core breeding work. The iSC considers this a very important development in strengthening the heartland of the CGIAR and in bringing new visibility to crop improvement and the international public goods it can create.

Sustainable Production Systems through Integrated NRM:

Integrated natural resources management (INRM) work in the System has continued to be under intensive scrutiny and assessment through a series of workshops convened by the CDC Sub-committee on NRM also referred to as the CGIAR Task Force on NRM. INRM 2001 (Cali) focused on operationalizing the INRM framework. INRM 2002 (Aleppo) focused on methods and approaches which have proven successful. The iSC has continued to work closely with the INRM Task Force and is collaborating in assembling a set of successful case studies to illustrate the underlying principles and concepts, the lessons learnt in applying these to actual problem sets, and how information technology, spatial analyses and modelling, and ecosystems approaches are enabling INRM research. Also, MTPs of IWMI, CIFOR, ICRAF and ICLARM as well as of CIAT, IITA, ICARDA, ICRISAT and IFPRI are providing further impetus to the integration in the Research Agenda of land and water dimensions with productivity and community dimensions of resource management which are benefiting from inputs of ecological, watershed and social sciences.

The iSC recommended the CP on Water and Food which it believes will provide a research framework that will bring the research and development community to address urgent major concerns as reflected in the international arena. If the CP does manage to mobilize the required additional funds, then water

management research in the CGIAR will finally begin to receive the kind of attention it deserves.

CGIAR's community-based participatory research efforts, as noted in a separate Commentary on CAPRi External Review Report, to define technical and policy options for collective action necessary for improved management of common property natural resources is beginning to show the importance of such research to the CGIAR goals of poverty alleviation and sustainable food security. Similar indications also appear from the results from PRGA. These Systemwide Programmes do point the way forward for CGIAR to divert resources towards social innovation research that need to accompany technological innovation research.

Socioeconomics and Policy:

As already indicated, investments in socioeconomics and policy research, whether viewed as *Undertakings* or as *Logframe Outputs*, are well above Group-endorsed targeted levels, and the trend will continue. It is not clear to what extent this represents a significant reallocation of System level resources, primarily away from Germplasm Improvement to socio-economics and policy analyses, versus simply a change in the way Centres are now apportioning activities and outputs. A definitive answer would require a more in-depth assessment, perhaps even down to the project level. It would appear, however, based on the narratives and information provided in the Centre MTPs and financing plans that some degree of reallocation has occurred. No doubt this is partly in response to the new Vision and Strategy of the CGIAR, with its stronger emphasis on poverty and its determinants (esp. ICARDA, ICRISAT) on the one hand, and the need for more attention to market analysis, business development and institutional reform (IITA and ICRISAT) on the other. CIFOR too is now emphasizing the importance of effectively using its resources to achieve impact through influencing important institutions and processes. Perhaps most important of all, there is a substantial increase in projected funding levels for IWMI, IFPRI and ISNAR over the three-year MTP period. All three Centres have a dominant or major share of their effort on socioeconomics and policy research. IITA too, is projecting a 59% increase in its allocation to policy research over the period.

Earlier in the year, CIMMYT and the iSC/SPIA organized an international conference on impact assessment (IA) of agricultural research and development in Costa Rica. The conference entitled "Why hasn't IA made more of a difference?" brought together over 145 participants with representation from most CGIAR Centres, many NARS organizations, universities, multilateral lending organizations, development assistance agencies, NGOs, philanthropic foundations and the media. In addition to addressing productivity, equity, environment and health impacts, papers dealt explicitly with hard-to-measure impacts in such areas as training, networks, participatory research and policy research, offering novel approaches to better evaluate impact. There is clear consensus and widespread interest in seeing the IA agenda move ahead rapidly. A paper highlighting the perceived needs and opportunities in system-wide IA was presented by SPIA in the final session. Three main areas where significant progress can be made in the future include: matching IA outputs to decision makers' priority needs; making IA outputs more credible, plausible and understandable -- without losing rigour; and, improving methods, particularly in terms of developing a set of impact indicators for a broader array of

impacts beyond the traditional economic ones. In addition to accountability, the objective of learning lessons needs greater emphasis in conducting IA.

Another particular effort by most of the Centres has been directed towards the CGIAR Social Research Conference organized by CIAT at the behest of the iSC. This Conference focused on the need for greater social and sociocultural research capacity in the CGIAR, given the new impact oriented Vision and Strategy and the increasing demand and need for participatory research for technological, social and institutional innovations and policy formulation. The Conference has highlighted a need to raise the status and capacity of social research in the CGIAR to ensure that research and products are environmentally as well as socially sound based on an effective integration of biophysical and social sciences at all stages of technological research process in the CGIAR. The outcome of the Conference is expected to be reported separately to the AGM, but the iSC considers that any recommendation to increase resources directed towards social research would need to be evaluated in the context of new CGIAR priorities and research opportunities.

Enhancing Institutions:

The MTPs at the System level are responding to the institutional environment characterised by an increasingly interdependent world as reflected in the outcome of the FAO World Food Summit-five year later and UN WSSD 2002 - where poverty alleviation, food security and environmental and social sustainability are intimately linked. CGIAR activities in enhancing institutions should improve the capacity of NARS scientific management of ecosystem goods and services; information and communication technology, for rural communities; food systems approach; environmental health and poverty indicators, impact and policy analysis; priority setting and strategy development. The iSC notes that Research Agenda increasingly address important areas such as biotechnology, biosafety, intellectual property management and GIS. Equally, linkages between agriculture, human nutrition and human health are receiving greater emphasis. However, building social capital and policy commitment necessary to shift from traditional institutional strengthening to modern institutional management requires greater attention. The Research Agenda is beginning to aim at institutional enhancement that will assist developing countries to put in place policies and mechanisms for cross-sectional and cross-institutional collaboration for effective social and economic development.

2.3.2 Resource Allocation Trends

The Group approved a new Vision and Strategy for the CGIAR at ICW 2000 as well as the need to prioritise CGIAR activities and resource allocation in terms of the following five logframe outputs: germplasm collection, characterization and conservation; germplasm improvement; sustainable production systems through integrated NRM; socioeconomics and policy research; and enhancing institutions. However, System level relative priorities between these have not yet been established and therefore the CGIAR currently has no resource allocation targets by logframe outputs.

The following changes from the Group-approved resource allocations for 1998-2000 period are apparent.

In terms of *Centres*, the 2003 financing shares of the CGIAR Research Agenda proposed by CIFOR, CIP, ICRISAT, ILRI, IRRI and WARDA are notably below Group-approved shares. These Centres face shortfalls of 15% or more, with ICRISAT and ILRI facing a shortfall more than 20%. On the other hand, financing shares of CIAT, CIMMYT, ICARDA, IFPRI, IITA, IPGRI and IWMI are above the Group-approved levels with ICRAF and IITA being above by 13% and 12% respectively, IPGRI by 23% and IWMI by 50%.

In terms of the CGIAR *Undertakings*, the trend of an increasingly higher share of resources allocated to Improving Policies continues. From the Group endorsed 12% target figure, the actual System-level allocation has risen from 14% in 2000 to 16% in 2002 and 2003 and is expected to reach 17% in 2005. Investments in Strengthening NARS remain above their targeted 20% level, at a constant 22% level through 2005. Conversely, there is relatively lower investment for Germplasm Enhancement and Breeding (20% approved for 2000 vs. 18% actual) that has continued to decease over time (17% in 2003 and 2005). Similarly, Saving Biodiversity has remained and is projected to remain at a steady 10% level through to 2005 vs. 11% approved for 2000. Of more serious concern is the discrepancy between targeted and actual (and projected) levels of investment for Production Systems and Management. The share of total investment in the Undertaking is expected to fall from 17% in 2002 and 2003 to 16% in 2005, while its targeted level is 19%. Protecting the Environment is the only Undertaking that consistently maintains its targeted level at 18%.

Thus, there is a shift in resources to Improving Policies perhaps at the expense of Germplasm Enhancement and Breeding which in 2003 and 2005 is expected to be 11% below approved level. There is also a continuing shortfall in investment in Increasing Productivity and Saving Biodiversity and continuing over investment in Improving Policies and Strengthening NARS. The continuing trend of increased allocation to Policy research well beyond the recommended level at the expense of Germplasm Enhancement and Breeding and Production System Development and Management is a cause for concern.

In terms of *Outputs*, although there are no approved targets set by the CGIAR, the trends are as follows. Resources allocated to: Germplasm Collection, Characterization and Conservation has remained steady at 10% since 2000, continuing at that level up to 2005; Germplasm Improvement is proposed at 17% for the period 2003-2005, down from 18% in 2002; Sustainable Production Systems through INRM is proposed to remain steady at 35% in 2003 but falls to 34% in 2005; Socioeconomics and Policy is proposed at 16% in 2003, up from 14% in 2000, and rising to 17% in 2005; and Enhancing Institutions at 22% steady over the period 2000 to 2005. Thus, allocations to *Outputs* in 2003 show a shift in resources towards Socioeconomics and Policy at the expense of Germplasm Improvement which falls in 2003 and 2005.

As mentioned earlier, the financial analysis and information provided by the CGIAR Secretariat does not allow any comments on resource allocation trends with regards to *Sectors, Commodities and Systemwide Programmes.* However, based on

ILRI's and ICLARM's financing plans, 2003 proposed allocations to the livestock and fish *Sectors* continue to remain below the recommended CGIAR allocation shares of 17% and 5% respectively. Allocation to IWMI is expected to exceed approved level by some 50% over the recommended 3.2% share of CGIAR funding, although it is not clear how much of this increase is directed to the water sector *per se* which is nonetheless expected to receive an increased level of investment previously called for by the Group.

Over the plan period 2003-2005, the allocation shares by *region* remain stable at sub-Saharan Africa 45% (increase from 42% in 2000), Asia 31% (decrease from 32% in 2000), Latin America 14% (decrease from 17% in 2000), and CWANA 10% (increase from 9% in 2000). Thus, Centre research agenda appear to have adjusted to the call for a stronger focus on sub-Saharan Africa but not for Asia which shows a decrease in allocation shares which is matched by a proportionate increase for CWANA. Again, as no investment targets for research in the regions have been formulated, it is not possible to make any comparative comments on inter-regional balance. However, in the future, it would be useful to monitor investments by subregions as well, e.g., Central America, South America, West and Central Africa, Eastern and Southern Africa; North Africa, Central Asia, West Asia, South Asia, Southeast Asia, East Asia, etc.

2.3.3 Concluding Remarks and Recommendations

The iSC offers the following concluding remarks and recommendations with regards to the System level process for the evaluation of the CGIAR Research Agenda.

The year 2003 is the third year beyond the 1998-2000 MTP period for which research priorities were formulated by TAC and approved by the Group in 1997. Also, the CGIAR reform process has led to the introduction of a third programmatic arrangement, the Challenge Programmes, in addition to Centre Core Programmes and Systemwide Programmes, for CGIAR research. It is not fully clear to the iSC how the Group wishes to monitor and evaluate the CGIAR Research Agenda in the future. Certainly, new MTPs submitted by Centres to the Science Council on a staggered and *ad hoc* basis will not provide a sound arrangement for a systematic annual evaluation of the CGIAR Research Agenda.

Also, the iSC notes that among the CP proposals there are many that stem from existing Systemwide activities. In a number of cases a Systemwide programme (SWP) mode would seem to be the most optimal one. There is a need to discuss the organization of CGIAR research which is being programmed and implemented at three levels: core programmes, SWPs and CPs, all of which should optimally contribute to the overall CGIAR Research Agenda. The iSC sees that in the future the Systemwide Programmes should continue to be considered as a valid and effective way of organizing collaborative research among Centres and with NARS and other partners. Lessons are being drawn from the experiences with the SWPs, most of which have been externally evaluated by TAC/iSC. Donor interest at initiation and subsequently is crucial for an effective start and viability. For improving the visibility and attractiveness of the SWPs, the performance monitoring should be made more

systematic. The implications of large funding fluctuations or terminations for continuing the research and to the partnerships involved deserve an analysis.

Given the drastically changed programmatic situation in the CGIAR, and the emerging resource allocation deviations described in Section 3, the iSC recommends that:

> ***The Group should request the future Science Council to undertake, in consultation with CDC/CBC, a review of CGIAR priorities and strategies so that System priorities across sectors, commodities, themes, logframe outputs and regions can be more precisely defined and articulated and against which the CGIAR Research Agenda can be objectively and systematically monitored and evaluated.***

Based on the AGM 2001 interpretation of the new responsibilities, the Science Council is expected to undertake periodic science evaluations of individual Centre project portfolio, including Systemwide Programmes, when Centres produce fresh MTPs every 3 years, and of the total project portfolio of the CGIAR System, referred to as the CGIAR Research Agenda. Also, the SC is expected to undertake *ex-ante* evaluation of Challenge Programmes, and monitor and evaluate their performance during implementation in terms of science relevance and quality. The focus on outputs and impact also requires that emphasis is placed in the SC to carry out impact assessment studies in a systematic fashion. Thus, a meaningful strategic evaluation of the CGIAR Research Agenda inclusive of the Systemwide and Challenge Programme and the resources directed towards CGIAR goals and outputs is not simple or straightforward. A new systematic effort must be put in place, given the multi-layered nature of CGIAR's output and impact oriented Research Agenda.

The iSC has elaborated its views regarding this matter in a document prepared for the Working Group on Science Council (see Annex 2). The iSC considers that the MTPs of the Centre core programmes, Systemwide Programmes and Challenge Programme constitute the basic documents against which Centre and System performance can be objectively and systematically analysed and evaluated, once System priorities across sectors, commodities, themes, logframe outputs and regions have been more precisely defined and articulated as recommended above. Consequently, the iSC recommends that:

> ***A systematic evaluation and monitoring process should be set up by the future Science Council, in consultation with CDC/CBC, to provide the CGIAR with a regular, complete overview of the System's Research Agenda and apparent gaps, and an evaluation of the overall agenda in the context of the CGIAR's mission and goals.***

2.4 Ensuring Assessment of the CGIAR System's Impact[2]

At iSC/TAC 82 and 83, the Council discussed the following studies of iSC-SPIA which are at various stages of implementation or completion. The iSC commends SPIA for its hard work.

[2] For details see iSC-SPIA Report to AGM2002

2.4.1 Environmental Impact Study

A report by prepared by Mywish Maredia and Prabhu Pingali on the negative impacts of productivity enhancing research entitled "Environmental Impacts of Productivity-Enhancing Crop Research: A Critical Review" was published and distributed earlier in the year. The main conclusions of these reports were highlighted in the TAC-SPIA Report to the Group at AGM'01. The authors concluded that it is not possible to develop aggregate quantitative estimates of negative environmental impacts—the compounding factors accounting for the linkages between research and environmental impacts are too complex to sort out given present analytical methods and available data. Evidence of negative environmental impacts has only been presented in the literature for a few GR crops, e.g., for rice (from pesticide use) and for wheat (from fertilizer/irrigation problems), and these are often associated with other causes, such as institutional or policy failure. Furthermore, there is, to date, little evidence of environmental damage resulting from other CGIAR mandate crops.

The other main report from this study, "Environmental Impacts of the CGIAR: An Assessment" by Michael Nelson and Mywish Maredia has been extensively revised to take into account comments on data and methodology used in the earlier version. While some of the quantitative results have changed, i.e., are more conservative, the main findings have not changed: Contributions by the CGIAR in the areas of germplasm enhancement and agronomy have permitted significant yield increases in farmers' fields, thus leading to less land being required to produce a given quantity of food crops. The Panel report is expected to go to green cover after a final review by iSC-SPIA members.

2.4.2 Germplasm Improvement Impact Study

Although a final report on this project was presented at MTM'01, subsequently a number of major revisions were undertaken by the authors in response to a thorough external peer review by three referees. While some numbers have changed somewhat, the basic conclusions remain as presented at MTM'01. The revisions are complete and CABI International is now in the process of finalizing proofs. The 23-chapter book containing the main elements of this iSC-SPIA activity, which documents the impact of CGIAR and NARS crop germplasm improvement, will be published in late 2002 or early 2003.

2.4.3 Training Evaluation and Impact Assessment

At TAC 79, the Committee commissioned an evaluation and assessment of capacity strengthening activities in the CGIAR. One part of this review is a study focusing specifically on CGIAR training. The CGIAR members and Centre representatives reacted positively to this idea, considering it both important and timely. It would provide a means to develop concepts, methods and data to use in the assessment of the other components of the overall set of capacity strengthening activities in which the CGIAR is engaged. Since TAC 79, TAC/iSC has continued to endorse the need for this activity, which will include a rapid appraisal type of stripe study on the current state-of-the art of training activities in the Centres and a research based assessment of actual and potential impacts. The implementation of this study

has been the joint responsibility of iSC-SCOER (Standing Committee on External Reviews) and iSC-SPIA.

The purpose of the training study is to evaluate the overall effectiveness of the training processes and outputs and assess the impacts of the CGIAR training activities for the NARS and identify how the activities could be improved. The study's broad objectives are to: (1) evaluate the quality and relevance of the training activities within the CGIAR, (2) evaluate the comparative effectiveness and efficiency of CGIAR training activities, (3) assess the intermediate outputs and impacts of training, and, to the extent possible, (4) assess the impacts of CGIAR training in the context of the CGIAR ultimate goals of poverty reduction and food security through sustainable production.

2.4.4 Impacts of the CGIAR on Poverty Alleviation

To determine how the poor have benefited from agricultural research, CGIAR Centres need a stronger capacity to undertake poverty impact assessments on a continuing basis, not only to identify the conditions under which agricultural research is a sound investment for reducing poverty, but also to improve the targeting of research priorities to the changing needs of the poor. A TAC-SPIA commissioned project implemented by IFPRI is developing and coordinating a cross-Centre initiative to strengthen capacity for such poverty assessments.

The first phase of this two-phase project, completed in 1999, involved a review and synthesis of the literature on the links between agricultural research and poverty, and a workshop to develop methodologies for further CGIAR impact studies. The second phase, which began in September 2000, planned 14 case studies to cover a wide range of countries and types of CGIAR research. The first wave of seven studies, launched in 2000, provides partial coverage of CGIAR Centres and types of research (e.g., in terms of commodity and regional coverage and scale of impact). The remaining seven studies—intended to target other CGIAR Centres and types of research—were put on hold due to lack of funding.

These studies have two main objectives: (1) to test empirically methods for evaluating the impact of agricultural research on poverty in the context of different agricultural technologies and within different country, social, and institutional settings; and (2) to develop a conceptual framework that CGIAR Centres can draw upon for impact assessment work, and that will also serve to guide priority-setting and technology design to increase the impacts on poverty. To accomplish these objectives, five of the first seven case studies used the sustainable livelihoods conceptual framework.

2.4.5 Conference on Impacts of Agricultural Research and Development: Why Has Impact Assessment Research Not Made More of a Difference?

The main outcomes of this iSC-SPIA and CIMMYT sponsored conference, held in San Jose Costa Rica in February 2002, are reported in a Proceedings document which is currently being finalized for publication. Participants included IA practitioners from 15 Future Harvest Centres, as well as representatives from NARS, public and private universities, multilateral lending organizations, development assistance agencies, NGOs, philanthropic foundations, private corporations, and the

media. With over 145 people attending, this conference was the largest gathering in CGIAR history of the international agricultural research IA community. The 4-day conference provided an opportunity for IA professionals to update their knowledge and skills in relation to both conceptual and empirical approaches to impact assessment while engaging in extensive discussion and networking. Participants highlighted experiences and case studies of impact measurement in the following areas: agricultural productivity; equity, poverty, social health, and nutrition; the environment; and, institutions and human capital. Participants also described novel approaches to hard-to-measure impacts in such areas as: training and capacity-building; institutional strengthening; networking; participatory research; and policy research.

2.4.6 Strategic Guidelines for IA in the System

The need for establishing strategic guidelines for IA studies in the CGIAR has been re-enforced at the last two major CGIAR sponsored IA conferences. The strategic guidelines will not be a detailed step-wise 'how to' manual for carrying out IAs, but rather a set of basic principles and discussion of strategic issues (including user needs) for IAs in the System. The document would cover issues that help link what users of IAs need (donors, planners, administrators) with what doers of IAs can do, given resource, and time and data constraints. It would explore basic issues such as the criterion of plausibility in IAs, attribution, development of counterfactuals, logframe and impact pathways analysis generally, and issues related to credibility, feasibility, transparency, and communication. Donors are keenly supportive of developing this set of guidelines, since such a document would be helpful to them in establishing internal guidelines for judging IAs and explaining them to funding and political bodies.

Since iSC/TAC 83 meeting, SPIA has drafted a preliminary annotated outline for these Guidelines. This draft was subsequently revised following a number of helpful comments and suggestions from various individuals, including iSC members, and some interested donors. In particular, EIARD members and USAID are quite interested and supportive of this work and are expected to be close partners in developing these guidelines. The plan is to bring on a consultant for 3-4 weeks to draft and help finalize guidelines, in collaboration with SPIA members and a range of other stakeholders. Centres will be involved centrally in this activity throughout the process. The major output from this activity will be a set of principles and 'best practices' strategies to guide ex-post impact assessment work done by the CGIAR and its Centres.

2.4.7 CGIAR Benefit - Cost (B-C) Meta-analysis

Since establishment in 1971, the CGIAR community has invested approximately US $ 6.7 billion (2001 inclusive, 1990 dollars) in various research and research related activities. In an era characterised by “donor fatigue” and scarce development resources, it is relevant to ask: *Do the benefits from CGIAR research justify the total investment in the CGIAR so far?* Although the CGIAR system has been a world leader in documenting research impacts, no previous study has attempted to comprehensively address this question. Thus, this study will represent a first attempt to scale-up extant productivity impacts to a System level.

The present analysis is intended to resolve on a preliminary basis whether the *entire* investment in the CGIAR over time can be justified on the basis of the benefits derived from its proven (and agreed-upon) major successes. One reason for the possible failure of prior impact analyses to offer very convincing evidence for continued donor interest is the criticism that such assessments have focused on the costs and benefits only of research successes, while ignoring the costs of failures or "dry holes." The present analysis offers an answer to such criticism by compiling reliable estimates of widely-recognised benefits, and comparing such with the ***total*** investment in the system to-date. Such an approach has already proven successful for other agencies and entities. To derive cumulative benefit values, the analysis will aggregate the most plausible benefit values from available, credible economic impact assessments for known successes.

2.4.8 CGIAR Impact in Africa Study follow-up

The major output from this activity will be an updating and extension of the work presented at MTM '01 seeking to document the improved technology and policy impacts of CGIAR and partner agricultural research in sub-Saharan Africa. The analysis will rely on two sets of information and data: field-level impact evidence from case studies and more general CGIAR Centre and System level assessments. Another key output, derived from the field study component, will be a longitudinal dataset over an extended number of years. This will be fundamental in capturing a better understanding of the linkages between agricultural research and poverty alleviation.

2.5 Evaluation of Challenge Programmes

At AGM'01, the Group assigned a new responsibility to iSC to undertake an evaluation of the Challenge Programmes in the pilot process as well as in the regular process. The three iSC reports, containing the evaluations and recommendations submitted to ExCo II and III, are on the Group's Agenda in the AGM'02 Stakeholders Meeting Agenda Item 5.

2.5.1 The Pilot Process

Pre-proposals: The iSC assessed 10 Challenge Programme (CP) pre-proposals for the accelerated pilot process as requested by the CGIAR Executive Committee at ExCo I in November 2001. It applied an evaluation process which took into account the 11 criteria approved by the CGIAR on a weighted basis as well as a peer review process involving some 25 external experts. The iSC used a modified Delphi approach to reach its decision which involved each iSC member evaluating all 10 pre-proposals in two rounds of e-mail discussions and exchange of views. The aim was to arrive at a ranked list of CPs on a relative basis.

Among the 10 candidates, the Genetic Resources pre-proposal was clearly number one, followed by the pre-proposal on Water and Food in the second place and on Biofortified Crops in the third. These three candidates met the criteria set for a CP pre-proposal and were recommended for Group's consideration for full proposal development.

The rest of the pre-proposals, except for that on HIV/AIDS, could not be discriminated sufficiently from each other but they were all considered as being very relevant to the goals of the CGIAR and therefore merited further consideration alongside the concept notes that had been submitted for evaluation in the regular CP process.

The pre-proposal on HIV/AIDS was considered to be responding to an important crisis, particularly in Sub-Saharan Africa, but the CGIAR Centres were deemed as not having the comparative advantage to lead a stand-alone CP in this area. However, a regionally focussed HIV/AIDS component could very well fit into a future sub-Saharan Africa submission.

Full proposals: The iSC evaluated the three CP full proposals, namely: (1) Unlocking Genetic Diversity in Crops for the Resource Poor; (2) Water and Food; and (3) Biofortified Crops for Improved Human Nutrition.

The evaluation process took into account the criteria for phase III of the CP process as approved by the Group. The assessment benefited from peer review by 21 selected scientists as well as from interactions between iSC Members, a few donor representatives and observers at the iSC/TAC 83 meeting and the lead proponents.

Based on the peer reviewers' comments and iSC's own comments, the proponents revised their original submissions, resulting in each case in improved versions of the proposals. The iSC endorsed all three CP proposals for the Group's consideration.

In transmitting its recommendation, the iSC highlighted the fact that these pilot CPs have major implications on the balance of our substantive activities across the logframe outputs. They impinge as well on the balance among centre core programmes, system wide programmes and the Challenge Programme portfolio. Also, there is concern that the novelty of the CPs would draw resources away from the heartland agenda in the Centre core programmes and jeopardize further the diminishing ability of SWPs to attract and retain donor support.

2.5.2 The Regular Process

The Interim Science Council (iSC) assessed 41 challenge programme (CP) ***concept notes*** in the regular CP process as requested by the CGIAR Executive Council (ExCo). Among the 41 concept notes, 35 were fresh submissions in response to the open call made on 15 November 2001, and 6 were left over from the pilot CP process.

The iSC applied an evaluation process which took into account the three broad criteria approved by the CGIAR at AGM 2001. The iSC used a modified Delphi approach to reach its decision which involved each iSC member evaluating all 41 concept notes in two rounds of e-mail discussions and exchange of views.

The iSC considered that the following 13 CP concept notes met the criteria set for a CP concept note and recommended them to the Group for ***pre-proposal development***.

Development of sustainable agricultural production systems in Central Asia & the Caucasus
Reducing poverty by removing market barriers caused by animal diseases
Securing livestock genetic resources for present and future food security
Increasing productivity in the coastal zone
Beating the heat: Climate change and rural prosperity
Harnessing global IPM initiatives
Urban harvest: A challenge programme on urban and peri-urban agriculture
Agriculture, poverty and combating desertification
Improving livelihoods and natural resources management in sub-Saharan Africa
The rainforest challenge: Forests as resources for the poor
Agricultural biodiversity for sustainable development
Biological nitrogen fixation
Sustainable mountain development

Brief comments on each of the above concept notes were provided in the report.

The iSC recommended further that in the call for pre-proposals for the successful concept notes/ideas, the proponents be advised to define more clearly their research objectives, the proposed methodologies, their expected outputs and the linkages between the research outputs and the expected impacts.

With regard to the rest of the concept notes that did not fully meet the criteria for stand alone CPs, the iSC proposed to endorse them to the appropriate CP proposals under preparation, to the Systemwide programmes and inter-centre activities for their attention and consideration, as appropriate

At the time of the preparation of this report, the iSC has been engaged in evaluating the above 13 pre-proposals submitted in August 2002. The iSC's evaluation will be transmitted by 19 October 2002 for Group's consideration.

3. Future Meetings

The next meeting is tentatively scheduled for late February/early March 2003 at IWMI, Colombo, Sri Lanka, and beyond that for early July 2003 at WARDA, Bouake, Cote d'Ivoire. The future Science Council is expected to take over in 2003. The tentative scheduling of the next two meetings in 2003 is for planning purpose only so that the iSC Secretariat and the Centre concerned are aware. It will up to the future Science Council to decide the exact date and venue of future meetings.

4. Concluding Remarks

The iSC has had an extremely busy and productive year in the implementation of its advisory responsibilities, and also in evaluating the Challenge Programmes in both the pilot and regular process. Several iSC Members took on extra work and the iSC, including iSC-SPIA, was ably supported by the iSC Secretariat staff. The iSC also received full cooperation from the CGIAR Chair and Members, ExCo, the Co-Sponsors, NGO and Private Sector Committees, CBC, CDC, Centres, GFAR, Regional and Sub-Regional Organizations, and the CGIAR Secretariat..

The Council expresses its sincere thanks and appreciation to them all. FAO's support as a host to the Council and to its Secretariat is gratefully acknowledged.

Since the iSC will give way to the new Science Council effective 2003, this is formally the last iSC Chair's Report to the Group. The Council and I express our appreciation to the Co-Sponsors, the Group and ExCo for the opportunity to serve the poor through the CGIAR System.

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Enhancing and Guarding the Relevance and Quality of Science in the CGIAR: An Operational Framework for the Science Council

SDR/iSC:IAR/02/07 Rev.2
iSC Working Document

CONSULTATIVE GROUP ON INTERNATIONAL AGRICULTURAL RESEARCH

Interim SCIENCE COUNCIL

Enhancing and Guarding the Quality and Relevance of Science in the CGIAR: An Operational Framework for the Science Council

iSC SECRETARIAT
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
August 2002

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1. Introduction

At AGM2001, the Group decided to transform TAC it into a Science Council (SC), with an interim Science Council (iSC) operating until the formal transition takes place on 1 January 2003. The Group also approved responsibilities for the Science Council (see Annex 1), and made other decisions regarding the role of the SC (see Annex 2, the AGM2001 Summary Records of Proceedings and Decisions pertaining to the SC). The basic role of the SC is envisioned as one of ***enhancing and guarding the relevance and quality of science in the CGIAR.*** In carrying out this role, the SC acts in a strategic advisory role, basing its advice on assessments, planning and evaluation functions.

In this context, *relevance* can be viewed as researching the "right things" to address the System's goals, and *quality* as researching the "right things well"[3].

For science to be *relevant* in the context of the CGIAR, it should address problems and issues whose solutions will have measurable, significant impact on the goals of the System. Thus, the relevance of the identified research priorities and strategies to the CGIAR goals and mission, and the nature of the planning and consultation process[4], including *ex-ante* analyses of need and potential impact to formulate the priorities and strategies, are important elements in defining relevance. The CGIAR vision and strategy provides a comprehensive framework for judging relevance.

Quality of science concerns four components, namely: inputs, processes, and outputs and outcomes of science. It has to do with the correct formulation of hypotheses, and with the appropriateness of scientific inputs, research methodologies and processes, and research outputs and outcomes. At the input end, the research "tools" (whether analytical, instrumental etc.) and scientific and disciplinary expertise being applied to do the research work are important quality parameters. Are tools and disciplines appropriate to the task being employed? Are new methods and techniques and new science being judiciously introduced? Thus quality of research inputs has to do with the appropriateness of the tools, methods and disciplines employed. As for quality of research process, what is the evidence that the research work being done is well executed and managed, including how effectively are the research milestones being achieved? At the output end, quality of research products has to do with scientific achievements and intermediate and ultimate outcome or impact. Thus, scientific quality deals with the efficient use of state of the art knowledge, research methods and protocols.

Within these definitions of quality and relevance, this discussion paper suggests an operational framework for implementing the decisions on the SC made by the Group at AGM2001. The paper serves as a starting point for the development of specific criteria,

[3] This definition of relevance and quality does not exclude the treatment of relevance as a dimension of quality, and *vice versa.*

[4] Planning for relevance is increasingly seen as an inclusive process requiring greater interface with the stakeholders of CGIAR research, not only donors, NARS and NGOs, but also organized groups of poor people (producer organizations, grassroots organizations). Demand for CGIAR research services should really originate in part from these stakeholder groups, particularly as they must also be involved in facilitating the effective implementation of research. This bottom up process of planning for relevance and coordinated implementation has been stressed in the CGIAR vision and strategy. This is an important aspect of the SC's role and that it needs to define a strategy that will enable it to guard relevance effectively.

procedures and guidelines for carrying out the responsibilities envisioned for the SC. The paper has been prepared by the iSC to offer its views to the Executive Council and the Working Group set up to facilitate the transformation of the iSC into a full Science Council.

The process of progress in the CGIAR is a dynamic one, an iterative process of successive approximations as the System adapts to the changing agricultural science and development environments in which it finds itself. This overall process of operation of CGIAR is laid out in Table 1, along with the context in which it takes place, and the role envisioned for the SC in the context of the activities undertaken by the other stakeholders in the CGIAR. The sections that follow consider each of the stages in the process outlined.

Thus, Section 2 looks at the SC's role in research planning and strategy development, given the goals and boundaries. Section 3 goes on to suggest the SC role in the organization and choice of research programme modalities, while Section 4 suggests the SC role during implementation of research. Section 5 then discusses the SC role in assessing the impacts of the CGIAR, through its research and its capacity strengthening activities. Section 6 suggests the potential role of the SC in making sure that past and present experience feeds back into planning and strategy development as the System moves through its iterative process of changes and adaptation to the changing environment.

2. Research Planning and Strategy Development

A first and fundamental task of the CGIAR is to develop the overall plans and strategies for implementing its research and related activities aimed at achieving its goals.

2.1 Scientific and Development Context

The main business of the CGIAR is the application of science for development leading to a food secure world for all. The CGIAR System's overarching mission is to achieve sustainable food security and reduce poverty in developing countries through scientific research and research-related activities in the fields of agriculture, livestock, fisheries, policy and natural resource management. Its overarching goal is to reduce poverty, hunger and malnutrition by sustainably increasing the productivity of resources in agriculture, forestry and fisheries. In a dynamic and political world, these goals need to be revisited on a regular basis to make sure that they are in tune with the needs regarded as priorities by the global fraternity of nations and institutions that support agricultural and related research for development and that benefit from it.

The new CGIAR vision and strategy calls for, *inter alia*, an increased emphasis on pro-poor relevant research, on regional and bottom up orientation, on bringing new science to bear on the often difficult-to-address causes of poverty and food insecurity, on the reorienting of the CGIAR towards undertaking critical Challenge Programmes. With these fundamental changes, the CGIAR is entering a new phase in its development. The new phase requires a much stronger concern for higher standards of scientific relevance and quality, for keeping pace with state of the art in world research, and for being relevant, selective and targeted.

Given that the CGIAR accounts for only some 4% of agricultural research in the developing regions, it focuses mainly on strategic and applied research of an international public goods nature, thus respecting the notion of division of labour between itself and its NARS partners[5]. As the ultimate responsibility for the adaptation and dissemination of improved knowledge and technologies rests with NARS and extension and development agencies, the CGIAR plays a catalytic role in the delivery of research products to the beneficiaries with whom it conducts participatory research and technology development work. It is for this reason that the capacity strengthening (research-related) role of the CGIAR is considered to be important and necessary.

2.2 Role of the Science Council

Relevant activities and strategies of operation for the CGIAR have to be chosen in this context of the existing and evolving global science and development environments in which CGIAR research exists. Further, priorities for CGIAR activity have to be planned and developed considering what others are doing and can do more effectively and efficiently than the CGIAR. The SC can maximize its support to the ExCo in planning and making the necessary choices of strategy by:

- monitoring changes in the global science and development environments and appropriately engaging in strategic and operational planning to suggest the appropriate role for the CGIAR in the context of these changes;

- monitoring the research and capacity strengthening activities conducted by others, and leveraging the comparative advantage of the CGIAR in given areas of activity, particularly through cooperation with NARS; and

- suggesting, in the context of these assessments of the global science and development environments, how the CGIAR strategically should proceed to carve out its niche and produce relevant, high quality, state of the art research to address the problems in which it has a comparative advantage.

Using the results of these SC assessments, the Centres and the ExCo, working with outside partners, can decide on an appropriate set of plans and strategies for organizing and implementing CGIAR research. It should be emphasized that the content of the CGIAR-supported research and related-activities implied by the resulting plans need to be derived in a consultative, sequential and iterative manner.

More specifically, this role in strategic planning is a fundamental anchor role of the SC in the CGIAR System as described in the responsibilities assigned to the SC by the Group (see items (b) and (i) in Annex 1). The SC should keep a watching brief on the global and regional external research and development environments and provides ongoing, independent and objective advice to the Group and its Centres on the context and significant trends that should affect priority setting and strategy development processes in the CGIAR. An important role for the SC here is also to keep the CGIAR informed of

[5] NARS, or National Agricultural Research Systems is an inclusive term that includes entities engaged in agricultural research and related activities in the public, private and civil society sectors. Thus, they include universities, national public agricultural research institutes, NGO organizations, private sector and farmer groups that are involved in improving agriculture, broadly defined, through research.

stakeholders' evolving needs and demands for new research and collaboration. This can be done through special studies (poverty analyses, regional analyses, etc.) but also through interactions with stakeholders (voices of the poor, interactions with regional organizations, etc.). This provides a basis for formulating the strategic planning context at the CGIAR System level.

To help focus on specific challenges or the potentials for new scientific applications, the SC would:

- interact with a wide range of experts and peers from the global science and development communities, to understand better the relevant scientific and development contexts;
- commission or mount itself *ex-ante* and *ex-post* strategic studies of relevant cross-Centre themes and activities (also of interest to CGIAR Members and the Centres) to help inform the formulation of plans and strategies;
- undertake periodic stripe evaluations of cross-Centre themes and topics to monitor science relevance and quality and formulate recommendations for future directions in research;
- organize and implement studies of regional research commitments of CGIAR in the context of Plank 4 of the CGIAR vision and strategy; and
- commission *ex-post* impact assessments of CGIAR research;
- keep aware of the factors affecting the comparative advantage of the CGIAR.

The results of all of these activities would feed into periodic reassessments and ongoing planning of the overall research agenda of the CGIAR.

Ex-ante strategic evaluations and perspective studies are undertaken to help identify, prioritize, plan and formulate science policy, priorities and strategies needed to most effectively and efficiently implement the CGIAR vision and goals., Such evaluations underpin the scientific advice and the debates that lead to the formulation and agreement on a strategic framework for reaching consensus on priorities, and for preparing the planning context and guidance for the System as well as Centre level strategic planning. These strategic evaluations and studies have been handled through stripe and inter-centre evaluations (e.g. farming systems, training, rice), strategic studies (e.g. plant genetic resources, soil and water, marginal lands, roots and tubers, post harvest), and regional studies (e.g. West Africa, Latin America). The SC would continue to provide such strategic analysis. The iSC is revising its existing basic document on strategic planning, in consultation with CBC and CDC and other stakeholders, and in the light of the new responsibilities of the SC. This will be available to the SC as it formulates its approach to meeting its assigned responsibilities.

With the addition of CPs to the array of research and capacity strengthening mechanisms, and with the complexity and time lines introduced by these new mega programmes, the role of strategic planning and evaluation of CGIAR future directions becomes all the more important. Since the new CPs represent major commitments of resources over longer periods of time and across Centres (i.e., at the System level), it is even more essential than before that the SC devote adequate time and effort to understand and prioritize relevant themes and the quality of the science proposed. TAC in the past has periodically prepared a System level "priorities and strategy" document for discussion and eventual approval by the Group.

3. Organization of Research: Programme Structure, Accounting and Governance[6]

The totality of the CGIAR's research and research-related activities may be summarized into five major outputs of the System log-frame format, namely: germplasm management, germplasm improvement, sustainable production systems through INRM, policy and socioeconomic research, and enhancing institutions. They may be classified by commodities, agro ecologies, themes as well as scientific disciplines.

The organization of research in the CGIAR has gone through a transition over the past decade. For the purpose of defining programme structure, accounting and governance, the System's totality of research and research related activities are organized and implemented, accounted for and governed as a continuum of three basic types or categories of programmatic arrangements, namely: (i) *Centre Core Programmes*[7]; (ii) *Systemwide Programmes (SWPs)*[8]; and (iii) *Challenge Programmes (CPs)*.[9] (Figure 1).

3.1 The Programmatic Context

The distinguishing characteristics of the three major forms of programmatic organization of research are outlined here below and in Annex 3.

Centre Core Programmes: The System's research and research-related activities are basically organised around the autonomous international Centres. The activities are planned, implemented, monitored and evaluated, and accounted for by the Boards and managers of the individual Centres/Institutes. The activities are supported by the Group members and other donors by way of unrestricted core funds and as restricted core and/or project support. Many contributions are also received in kind i.e. through secondment of scientific staff, equipment donations, as well as use of facilitation and experiment stations.

In addition to those activities directly and exclusively conducted by the staff of the individual Centres, are many research and research-related activities implemented and jointly conducted by the Centres with national and other partner institutions through various networks and consortium which the Centres have organised and led.

These two sets of activities constitute the Core Programme of an individual Centre, all of which are accounted and reported under the supervision and control of the Centre Board. The Centre Board in turn is accountable for their activities to the Group and other donors.

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[6] While this is not a final and definitive outline of programme organization, it is necessary to lay out the broad programme thrust in order to be more specific on assessing relevance and quality of research.

[7] Research in the Centre Core Programme is supported through unrestricted and restricted donor funding.

[8] Include global and regional subject matter or thematic programmes, and programmes with an ecoregional approach.

[9] Challenge Programmes are the latest modality adopted by the CGIAR System. These projects generally are large, focused on solving a given major issue in a finite, defined time period, represent partnerships with non-CGIAR organizations, and involve cross disciplinary activity.

Systemwide Programmes: Systemwide Programmes cover sets of activities conducted by the Centre among themselves and with various national and partner institutions with specific objectives in mind. However for the most part they are organised and recognised as such to provide scientific coherence to the totality of System activities on a specific theme or problem area and to promote efficiency and effectiveness in their planning, implementation and delivery. They are usually activities no individual Centre can pursue on its own with equal success and those activities which clearly are best conducted in partnership with others.

To provide coherence, direction and scientific quality control on these activities, a scientific Steering Committee is organised by mutual consent among the partners. The Steering Committee is composed of key scientific investigators representing the partner institutions, among which one is designated as Systemwide Programme leader/co-ordinator, director or appropriate.

In recognition of initiative, scientific leadership and/or substantive resource commitments, the co-operating partner turn to one of the Centres to become lead or convenor, and to reduce transaction costs as well, the finance and administration of the Systemwide Programme are entrusted to the Board and management of the lead/convenor Centre.

The designated Systemwide Programme leader is usually a key scientific leader/manager of the convenor Centre and is endowed by the convenor Centre and the member parties with appropriate management and decision-making authorities.

A key feature therefore of Systemwide Programmes is that governance and accountability to the Group, as well as to the co-operating partner institutions, are entrusted to the management and Board of the convenor Centre.

Challenge Programmes: Challenge Programmes are organisational instruments designed not only to provide coherence and direction to System activities on a specific theme or problem area and to promote efficiency and effectiveness in their conduct. They are likewise intended to provide the System's impact on its stated goals of poverty alleviation, promoting food security and enhancing the sustainability of natural resources by drawing in new, additional partners particularly those involved in development and utilisation of the System's research outputs, as well as those institutions leading global efforts in conventions and initiatives with similar and/or related goals.

By articulating the System's activities to those global activities related to poverty alleviation, food security and environment protection by way of Challenge Programmes, the System's activities hopefully will be given the attention and political support they deserve.

As in Systemwide Programmes, a scientific Steering Committee will normally provide coherence, direction and science quality control over the activities of each Challenge Programme. However in view of the significant involvement and commitments of partner institutions beyond the CGIAR Centres themselves and their regular NARS counterparts, a Stakeholder Board may usually be necessary to provide accountability and formal governance to these global partnerships or alliances. The Stakeholder Board of a

Challenge Programme will consist of individuals representing the perspectives/interests of its manifest stakeholder.

The terms of reference, composition, costs and details of these administrative, management and governance arrangements and structures will be as provided in the Challenge Programme's *business plan* agreed to by the partner, and approved by the CGIAR.

3.2 Role of the Science Council

Challenge Programmes are chosen through a competitive process that involves the SC. The SC provides the process for assessing, weighing and developing recommendations for choice of CPs; it forwards a list of recommended priority CPs to the Executive Council, which then decides on which CPs are to be funded and at what levels. In the process of assessing CPs, the SC also should take on the role of recommending improvements to the organizers of such.

In the category of **Systemwide Programmes**, CGIAR currently has eighteen Programmes ongoing in various stages of implementation, of which eight are classified as ecoregionally focused SWPs. Decisions remain to be made by the Executive Council on the way forward in terms of organizing new SWPs. The iSC currently is in the process of debating its perspective on SWP modalities and on the most desirable and effective means of proceeding with consideration of new SWPs, of which several ideas already are on the table, with some already ongoing as inter-Centre activities.

With regard to the organization and balance of **Centre core programmes**, the role of the SC is to evaluate and comment on Centre medium term plans (MTPs). The SC forwards the results of such deliberations to the Executive Council for use in making its decisions on the level of investment in the CGIAR. In the process of the SC's deliberations it could provide useful input for future planning in the Centres. It may be desirable to develop a more operational and systematic mechanism for assuring such feed back to Centres.

4. Implementing, Monitoring and Evaluating Research in the CGIAR System

Research in the CGIAR is undertaken by the Centres with their partners through Core Programmes, Systemwide Programmes, and, in the future, through Challenge Programmes with outside partners. In fact, implementation of most CGIAR research involves partners, most often right from the initiation of the research planning leading up to the research. As such, mechanisms need to be developed to include such partners in the monitoring and evaluation of research. That implies development of sound accountability mechanisms, where such can be shared appropriately among partners.

The Centres and their Boards ultimately are responsible for monitoring and evaluating their own research for both quality and relevance. The System, primarily through its SC, monitors and evaluates the adequacy of such Centre monitoring and evaluation activities to be able to ensure the members of the Group that the Centres are producing transparent, quality results in their internally mounted evaluations. On

occasion, the SC would mount its own, independent evaluation of the Centre's science relevance and quality.

In addition to Centres, the System has SWPs and CPs. M&E for these cross-Centre Programmes could be undertaken through the Programmes themselves, and through independent evaluation mounted by the SC.

4.1 Guiding Principles

Any scientific endeavour that aims at being relevant and of high quality should be both effective and efficient in its conduct. In most, if not all, scientific institutions, there exist mechanisms to ensure that research programmes are carried out as effectively and efficiently as possible, as part of the process of self-accountability as well as of accounting to Investors for resources utilized in research. Such mechanisms are based on both internal or self and external evaluation[10] processes.

Self-evaluation and assessment is an integral part of responsible management. Performing institutions invariably have quality control mechanisms in place to set benchmarks or standards as well as for monitoring progress (or lack of) towards meeting the agreed standards.

In the CGIAR Centres, this function of assurance of relevance and quality of science is implemented through:

- Self-assessments and internally managed external or peer reviews as an integral part of responsible management and governance;
- Built-in mechanisms for supervision and personnel evaluations by the Centre managements and the Boards;
- Recruitment and retention of world class scientists, including attractive conditions of service;
- Supervision exercised through research programme leaders, research directors, DDG-Research;
- Policy oversight by Programme Committees of the Boards which are guided by the longer-term strategic plans and medium-term operational plans;
- *Ex-ante* reviews of projects and programmes by programme leaders and Directors of Research, sometimes with external peer input; and the various internally managed review and evaluation processes, including peer reviews of particular projects and activities, peer participation in annual programme reviews.

[10] The word evaluation is an abstract noun, and can mean different things to different people unless it is defined explicitly. The iSC defines evaluation as follows. Evaluation is to do with finding or ascertaining or appraising or assessing the value of an activity, event, object, etc. The word value refers to the worth, desirability, utility and the qualities on which these depend. Thus, in the context of science relevance and quality, evaluation is defined as a process and products thereof undertaken to examine the value in terms of relevance and quality of past, present or proposed activities in relation to their purpose and context. Evaluation of a proposed activity or theme is referred to as *ex-ante* evaluation, and so are evaluations (perspective studies, strategic studies) undertaken for planning or setting planning context and formulating priorities and strategies; evaluation undertaken during the implementation of an activity is referred to as *performance monitoring or monitoring and evaluation;* and evaluation undertaken on a completed or a past activity is referred to as *ex-post* evaluation which may also include *ex-post* impact assessment.

- *Ex-post* reviews which have included the strengthening of impact assessment in recent years.

While self-assessment processes involving internal experts is a necessary element, Centres increasingly recognize the value of inviting external experts and peers in assisting to enhance relevance and quality of science. In the same vein, there is now a better appreciation of the pivotal role of the Centre Boards and management on quality assurance. However, the iSC considers that there is still important room and need to strengthen *ex-ante* science review processes in the Centres, on a project by project basis. Further, given the need for incorporating greater concern for higher standards of quality in the CGIAR science culture, the achievement of highest scientific relevance and frontier level quality must become more than ever before the personal cause and the guiding value for each researcher in the System, for each research manager, for each Centre Director and administrator.

Donors also undertake evaluation especially for restricted research projects, but also when they provide fully or targeted unrestricted support in which case broad strategies and outputs and outcomes are examined.

However, for scientific research, the necessary internal assessments, however effective, are not deemed sufficient. Independent external evaluations by outside peers, both *ex-ante* and *ex-post* are *de rigeur* to enrich approaches, to enhance scientific credibility as well as to foster accountability to investors for resources expended in the enterprise. While some progress has been made recently in promoting *ex-post* peer assessments, systematic mechanisms for *ex-ante* peer evaluation processes have yet to be introduced in the CGIAR System.

Thus, the relevance and quality of the research practised in the CGIAR should continue to be assessed through both internal and external evaluation processes. There is a need to build a genuine evaluation and impact culture in the System, including amongst Investors, within the SC, the Centres and with each scientist in the Centres. Within such a culture, a much clearer focus on outputs and impacts within the Centres and in other entities within the System is highly desirable.

The key to independence in assessment is that it be transparent, objective, and unbiased in terms of selection of subject (programmes and projects) and in process. Consequently, even when major proportions of the Centres' portfolios are made up of special projects reviewed directly by investors, there was a perceived need for independent evaluation by external peer sources that do not have a vested interest in the activity being evaluated.

While accountability assurance is a main purpose for much of the evaluation in the System, an equally important and closely linked purpose is to provide information and feedback for the strategic planning of new areas of emphasis and areas to diminish or phase out. It is evident that such planning should draw heavily on the self-evaluations and impact assessments carried out in the Centres and within the context of the regional fora and other groups focusing on regional research needs and priorities. Also, in shifting the focus towards CGIAR outputs and impacts, special care needs to be taken to ensure balance between immediate or short term outputs/impacts and the quality of science and research that will help ensure the flow of future outputs and impacts.

4.2 Internal Centre Evaluation Processes

The iSC proposes that, at the Centre level, the internal evaluation process would proceed as follows:

With oversight from the BOT, Centre management will design and implement a comprehensive continuous self-evaluation procedure. It will cover the relevance of research and related activities, including planning for relevance and stakeholder consultations; the quality of scientific inputs and research methodologies, outputs, intermediate outcomes and impacts; and the efficiency and effectiveness of operations, including research partnerships and delivery of research products. Centres should develop procedures for in-house peer assessments of research proposals both *ex-ante* and *ex-post*, making use of the existing expertise in the network of CGIAR Centres, as well as procedures for the review of specific areas and programmes. To the extent necessary, keeping in mind the costs involved, the Centres are encouraged to engage external expert reviewers in these processes.

At the programme level, there should be mechanisms to operate the internal monitoring and review of planning processes, achievement of milestones, roles of partnerships and all other specific activities. The template for these has been installed in the log-frame planning format. In all cases, the output from the internal evaluation processes are expected to provide an input into the external independent processes overseen by the SC which also assesses the appropriateness and effectiveness of the internal evaluation processes for assurance of science relevance and quality.

The iSC considers that it is extremely important to set out clearly the positive image of *ex-ante* peer evaluation as an instrument for enriching each research proposal before it is approved for funding, with benefits of knowledge and creative suggestions from groups of researchers invited to join in the peer evaluation process. The author of each proposed research project will gain from the state of the art knowledge on the subject and from additional suggestions from peers regarding investigation techniques, design of experiments, consultation with beneficiaries, etc. This should counter in a positive and constructive way the fear about ex-ante peer evaluation as a simple administrative or "police" procedure. Peer evaluation can also sharpen the relevance of science, not only its quality, and could definitely help promote the best use of financial resources in the service of the most relevant and high quality research proposal. Further, *ex-ante* peer evaluations will facilitate bringing into the CGIAR System ideas, knowledge, and techniques from outside the System by inviting outside researchers to mix with in-house researchers in the peer evaluation rounds. In short, to use the words employed during the AGM2001, "we need a world class peer review system to help produce world class quality research."

Consistent with the guidance given at AGM 2001, the iSC has initiated the preparation of guidelines for introducing state of the art mechanisms for *ex-ante* peer review of proposed research projects, or for strengthening it where it already exists. The AGM emphasized that *ex-ante* peer review should be applied to all research projects, rather than only to the new CPs. The iSC is in the process of commissioning a study on existing good experiences with ex ante review mechanisms outside and inside the CGIAR. On the basis of the results of this study, the SC would prepare recommendations that would provide guidelines for the design of an *ex-ante* peer review process, tailored to the

objectives of enhancing the quality and relevance of research and science in the CGIAR, and periodically evaluate its effectiveness. The proposition is that Centres will design and implement a self-evaluation procedure. It seems that more emphasis needs to be placed on the role of and procedures for peer reviews, with guarantees of anonymity for peer reviewers as a routine procedure for at least a significant share of the review exercises (clearly not for all when reviewers are teams of experts coming to a Centre). Centre research plans and scientific papers can be submitted for external peer reviews through anonymous procedures. DGs would be expected to have consulted in this fashion the most respected experts in the field. Anonymity and freedom to criticize are essential to peer reviews in advanced research institutions.

While the Boards' oversight role of the internal evaluation processes has improved in recent years, there is much more potential for incisive and in-depth engagement of Boards in quality assurance processes beyond their traditional role of monitoring and approving overall programmes and LTPs and MTPs. There is enormous scientific competence embodied in the memberships of Centre Boards and Board members should be used more intensively for quality enhancement purposes. For instance, working groups could be constituted among members of each Board requiring them to participate in the *ex-ante* peer evaluations of individual projects.

The iSC recognizes that the Centres are long standing, well organized institutions that are well-placed to develop, implement and maintain the self-assessment mechanisms described above on a continuing basis. Basically, the proposal is to rely much more on a Centre managed external peer review system (PRS). This approach is put forth on the premise that Centre BOT processes and performance are assured. With such assurance (which can be monitored in several ways), preliminary thinking is that the rest of the centre review process might proceed as follows:

- With oversight from the BOT, Centre management will design and implement a continuous self-evaluation procedure that focuses on efficiency in operation, quality of science outputs and relevance of impacts. The core of this approach will be the PRS mentioned above. The SC will prepare guidelines for consideration by centres in preparing the procedures.
- The overall self-evaluation process would include, at a minimum, procedures for evaluating:
    - the relevance and impact of the research, both on-going and completed;
    - the quality of the science used
    - the efficiency with which research resources are used (including an assessment of the appropriate role of partnerships and capacity strengthening activities in meeting the centre's goals).
- The evaluation should focus on both present outputs and impacts and on the quality and relevance of ongoing science as the most objective indicator of potential impact. This should include an assessment of the quality of staff, recognising that good science is only possible with good staff.
- Results of the self-evaluations would be adapted to the common format provided by the Logframe, currently adopted by all Centres. This information will be used to consolidate the outputs, milestones and impacts of each project into a central

Management Information System (MIS) for the whole CGIAR, including the individual centres.

- This information would be systematically reviewed (annually) by SC in its oversight capacity. SC would report the results of its review in an annual "Science Report" to the Group and executive body of the CGIAR. This would emphasize scientific breakthroughs and notable achievements, as well as gaps and constraints. This would serve as a benchmark against other relevant scientific institutions and help document science progress over the CGIAR System as a whole.

It is important to recognise that the development of a centre focused self-evaluation process would take time. Although this would be an evolutionary and learning process, the steps of transition must be planned carefully. The SC would be expected to prepare new programme evaluation and assessment guidelines and benchmarks in consultation with centres, investors and other interested stakeholders of the System and develop an appropriate management information system as the centres gear up for a full scale internal-review process.

4.3 External Independent Evaluation Processes

External independent[11] assessment and advice has always been a key pillar in guarding and enhancing the quality and relevance of the CGIAR's research. From its inception, a Technical Advisory Committee (TAC) composed of knowledgeable scientists representing a broad range of disciplines drawn from all over the world was organized to provide the Members of the Group as well as the Centres independent, objective and rigorous advice on research objectives, directions, priorities and strategies as well as assurance of relevance and quality of science practised at the Centres.

Under the SC, external evaluation at the **Centre level** would be of two kinds:

Periodically (roughly every five years), an independent external programme (or science) evaluation of each Centre will be commissioned by the Science Council[12]. The evaluation will be organized and managed by the Science Council with the help of its Secretariat. The evaluation will concentrate on the Centre's *processes* for assessing the relevance, quality and impact of research and related activities, and on the efficiency of resource use. The evaluation will also help the Centre reassess its strategic vision and set new research priorities. The evaluation will draw heavily on the results of the internal evaluations and assessments, and thus will supplement the Centre-managed process. It may thus be considered to be an 'audit of audit processes' and will be far less time consuming than the current external programme and management reviews.

The second kind of external evaluation at the Centre level should address the medium-term plans (MTPs). Centre MTPs will be assessed as a group every 3 years by the

[11] The word independent here refers to the basic purpose of the SC which is to ensure that its advice to the Group and CGIAR System is objective and impartial in addition to being transparent in terms of the advice is formed or developed.

[12] When the SC commissions an independent evaluation, it does so on behalf of the Group, deploying expert panels or individual experts depending on the task at hand. The experts serve in a personal capacity.

SC, to provide the CGIAR with a regular, complete overview of the System's research agenda and apparent gaps, and an evaluation of the overall agenda in the context of the CGIAR's mission and goals. Information from the external evaluations will feed into this process. The MTPs will then constitute the basic documents against which Centre performance will be evaluated. This implies a need to more precisely define and articulate System priorities across sectors, commodities, themes and logframe outputs. In this context, Centre MTPs can be more objectively and systematically analysed.

At the SWP and CP levels, the SC would commission external science evaluations at the various stages of Programme development and implementation in the context of System level resource allocation to geographical regions, sectors, commodities, Centres, Programmes, enterprises and outputs. (It should be noted that SWPs and, particularly the more independent CPs also should have well developed and articulated internal monitoring and evaluation processes).

4.4 Evaluation of Systemwide Programmes and Challenge Programmes

The iSC has had to develop initial criteria and procedures for evaluation of concept notes and pre-proposals on the new CPs. Further analyses and refinements of such criteria are being made as well as for the guidelines and criteria for evaluation of the final CP proposals. Similar approaches will be proposed for the evaluation of Systemwide programmes based on the revision, in consultation with CBC, CDC and other stakeholders, of the current TAC/iSC document on the external evaluation process for Systemwide Programmes.

A several step process has been put in place to review and assess Challenge Programmes. This allows Centres and their partners to progressively invest in the programme as their probability of CGIAR approval and support grows. The role of the iSC is to bring the best scientific judgement to bear, through internal iSC expertise and through panels of external reviewers who collectively have knowledge of the relevant cutting edge science and of its application to development needs. Those panels include scientists and development specialists from advanced laboratories in both the north and the south, and representatives from both developing country NARS and NGOs. The external review process is broadly selective, and protects the anonymity of the reviewers according to procedures widely used in proposal review in other institutions.

In the pilot CP phase priority was given in the concept note and pre-proposal phases to the scientific potential for problem solution given the predominant capability and comparative advantage of the Centres, and the potential for major impact on poor people and on critical and growing environmental problems. Evaluations were made on strategic issues and very general statements about scientific approaches. In the review of full proposals the programmes will become much more specific. The role of the iSC now turns to assisting the proponents of the three selected programmes to formulate them in the most effective way through feedback from external reviewers and from the iSC commentary.

It is envisioned that the CPs will go through an evolutionary process as governance structures are put in place, partnerships consolidated and work plans evolved. It is assumed and strongly recommended that all CPs and SWPs be immediately brought into

the MTP process following the CGIAR logical framework structure. As TAC conducted its overall review of SWPs with an ecoregional approach and more recently of theme-specific SWPs, a major constraint in the review process was the inability to sort out normal Centre Core programme activities from those of SWPs. If such SWPs are to be held accountable they must have identifiable structure. The structure must be consistent with the logframe process of the CGIAR. That logframe was developed, in fact, anticipating the complex processes of future programmes.

The Science Council should carefully review the first MTPs (business plans) of the CPs to assure that the various elements of the logframe are in place: Beneficiaries, goals, objectives, intermediate goals and milestones should be clearly identified. Impact pathways should be clear. Programme evaluation and impact assessment would then follow internal and external review processes similar, but not necessarily identical to other Centre and programme reviews. The System should bring all Systemwide Programmes under this same logframe-based MTP and programmes review process.

The financial structure will be complex for partnerships formed in the new CPs, with combinations of targeted and attributed funding. This structure should be clear, with the ExCo and System Office overseeing its clarity. The problem of redundancy or overlaps in accounting also needs to be clarified. As subsidiarity is a key element and a fundamental principle of all of these programmes, the resources will appear in more than one place and must be sorted out in aggregation at various levels.

Scientific accountability will not necessarily (and probably never will) coincide in scope, with financial accountability given the attributed nature of many of the resources brought by non-CGIAR partners who are not operating under contract. The attributed resources should be footnoted only according to standard accounting procedures within the CGIAR System, but the scientific contributions of such partners may be critical to the success of the project. In programme evaluation the review process must then assess the adequacy of output of those partners, even though they are not strictly accountable in a financial way. This has to be done with discretion and appropriate sensitivity, but it is critical to programme success and accountability. Scientific accountability and review will almost always be more broad than financial accountability. Review panels and all partners should understand this distinction.

Once the pilot CP process is complete and the second round is more advanced there is an urgent need to reassess the role of Systemwide Programmes in relation to CPs and centre core programmes. There seems to be a need for such "intermediate structure" programmes with less formal governance to tackle more specific issues. The "why and how" for these SWPs should be articulated with respect to CPs. That will be an issue for the regular CP process which is now underway. The new SC will have a central role to play in this process.

Based on the AGM2001 interpretation of the new responsibilities (Annexes 1 and 2), the SC is expected to undertake periodic science evaluations of individual Centre project portfolio when Centres produce fresh MTPs every 3 years, and of the total project portfolio of the CGIAR System, referred to as the CGIAR research agenda. Also, the SC is expected to undertake *ex-ante* evaluation of Challenge Programmes, and monitor and evaluate their performance during implementation in terms of science relevance and quality. The focus on outputs and impact also requires that emphasis is placed in the SC

to carry out impact assessment studies in a systematic fashion. This is discussed in the next section.

5. Impacting Poverty, Environment and Food security

Ultimately, the objective and purpose of CGIAR research and related activities is to have positive impact on reducing poverty, enhancing the environment and its sustainable use, and food security. This impact focus has to be built into every CGIAR project, whether at the Centre or cross-Centre and Challenge Programme levels.

5.1 Impact Culture Context

Centres are in varying stages of introducing an "impact culture" into their daily operations. Most Centres undertake impact assessments, again with varying levels of sophistication and success. A great deal of discussion and activity in this area is on going in the System, and more is needed in the future, as the need for increasing efficiency and effectiveness in programme design, development, implementation increase. Centres are increasing being held tightly accountable for their use of resources. At the same time, there is increased need for assessments of impacts to inform internal planning of programmes and activities and in setting priorities among alternative uses of resources. All units making up the CGIAR have a role to play in furthering the effectiveness of impact assessment in the System.

5.2 Role of the Science Council

How impact assessment (IA) activities are organized in the SC remain to be determined by the SC once it is established. However, it is clear from AGM2001 that the Group wishes this function at the System level to be part of the SC responsibilities (see item (iv) Annex 1). From the iSC perspective, the SC should ensure that the strong operational linkages to the forward planning (see section 2) and monitoring and evaluation of on-going programmes (see section 4) be maintained. The three functions are complementary and depend on each other in a dynamic feedback process that is so essential to assuring that the CGIAR remains on the frontiers of science and development, maintains its science quality and relevance, and contributes in the most effective and efficient manner to the goals of the Group.

Within this broader context of CGIAR forward planning, monitoring and evaluation of on-going programmes, and accountability to investors for past use of their resources, the iSC believes that the System needs

(a) evidence of the impacts of its various completed and on-going research and related activities,
(b) impact information useful in understanding appropriate and desirable changes in direction of the System's programmes, and
(c) mechanisms for strengthening the capacity to do impact assessment in the System's Centres.

Within this context, the SC IA activity should:

- work with Centres in strengthening Centre IA capacity and linking activities;
- undertake System level impact assessments that involve inter-Centre cooperation and collaboration;
- work more closely with the System's science monitoring and evaluation activities to ensure that the complementarities between IA and M&E are fully realized;
- provide *ex-post* impact assessment outputs that can serve the purposes of planning the new Challenge Programmes and reorienting overall System plans, i.e., work more closely with the forward looking planning activities performed at System level;
- open up more broadly to the outside evaluation/impact assessment world, including through networking, outsourcing and implementing some of its future studies on a broader, competitive "request for proposal" basis, and
- develop a systematic process to assure high quality, independent scientific peer review of all its analytical studies and their results.

Specifically, the iSC concludes that there is a continuing need for four main *ex post* impact assessment functions at the System level within the CGIAR:

(1) Conducting high quality, independent impact assessments to provide results of use to (a) investors, in justifying their investments; and (b) System management and Centres in planning their programmes and investments and developing and allocating budgets.

(2) Tracking information related to the impacts associated with Centre and cross Centre activities. This could involve routine data collection; and developing, maintaining and managing, in collaboration with the planning and monitoring and evaluation units, an appropriate data base/MIS for the System that would provide annual updates on accomplishments (training, research, etc.) in addition to data on other indicators of relevance in understanding the impacts of the System's outputs and processes.

(3) Developing methodologies, providing training in their use, and providing advice and facilitation for Centres as needed, e.g., in terms of setting up programmes and projects in such a way as to make tracking and analyzing impacts more feasible, transparent and of high quality.[13] This would include the "certification" of quality of internal IAs and organizing and "certifying" quality of external IAs. Ideally, this function would involve the establishment and maintenance of a CGIAR wide IA web site that also would be open to all outside entities with an interest and involvement in IA related to agricultural research and training.

(4) Delivering and facilitating the most effective use of the outputs of the IA entity, e.g., facilitating Centre interaction and learning, and development an effective impact culture in the Centres. Centre scientists have adapted rapidly to the output-orientation of the Systemwide logframe, but in the more complex projects that they are working in, the connectivity of their outputs to impact may not always be evident. Quantification through impact assessment greatly helps in underscoring an impact-

[13] It should be stressed that the implication of this statement is not that the Centres are lacking in high quality impact assessment capacity. Rather, the thinking here is that a central entity can facilitate interaction among Centres, gain access with System level resources to expertise needed by all Centres, and provide a clearing house for information and documentation of use to all Centres. In a sense, this central entity will provide "System level public goods."

oriented culture. It also would involve providing insights to investors on what is and is not feasible in terms of carrying out IAs for such activities as natural resources management, social science research and capacity strengthening.

The iSC continues to see impact assessment as a central function of the new SC, in agreement with the recommendations coming out of AGM01. The synergies between the overall mandate to guard the quality and relevance of science are strong.

6. Linking the Past and the Present with the Future: the Feed Back Dynamics

One of the strengths of the CGIAR has been the existence of feed back mechanisms where Centres and the System learn from the past mistakes and successes and adjust programmes and organizational mechanisms to the lessons learned.

6.1 Context

The CGIAR exists in a dynamic environment of evolving science and changes in development that should influence the priorities and activities of the CGIAR. Mechanisms need to be developed to make sure that relevant lessons from the past and present feed into plans for the future of the System. This is a major part of guarding and enhancing science quality and relevance.

6.2 Role of the Science Council

The SC should build effective working links between its functions of **impact assessment** – learning about past successes and failures in terms of moving towards CGIAR goals, performance monitoring or **monitoring and evaluation** – learning about on-going programmes and the state of implementation of current plans, and **forward strategic planning –** bringing together the best available knowledge of outputs, impacts, relationships, trends, and changes in the scientific and development environments to develop plans for future priorities and strategies of the CGIAR. Such linkages can be developed by establishing working relationships between those in the SC and its Secretariat who become focal points for its forward planning, monitoring and evaluation, and impact assessment activities. The results of activity coming out of such working relationships can help generate more effective and efficient programmes in the System, including better quality and more relevant science. The SC should explicitly build into its programme mechanisms to ensure that the particular dynamics of the CGIAR System is fully exploited in moving ahead.

The Responsibilities of the Science Council

"The primary responsibilities[14] of the Science Council are to:

a. serve as guardian of the relevance and quality of science in the CGIAR, and

b. advise the CGIAR on strategic scientific issues relevant to the Group's goals and mission.

The SC should assist the ExCo and its Programme and Finance committees by providing them with scientific advice on the strategic framework and set of priorities conducive to achieving CGIAR objectives.

Specifically, the SC would:

i. conduct periodic assessments of global and regional trends, scientific challenges, and research opportunities; and prepare the planning context at the System level;

ii. provide a critical review of System-level strategic plans and the CGIAR project portfolio;

iii. review Challenge Programme proposals; mount peer review mechanisms, as necessary, for review of the proposals; and

iv. coordinate the CGIAR's science monitoring and evaluation (including oversight of the peer-review and other quality assurance mechanisms used by the Centres) as well as System-level impact assessment activities."

[14] From Attachment 5, Science Council Responsibilities and Composition and Transition from TAC to Science Council, CGIAR AGM2001, Washington.

Matrix of Responsibilities[15]

Product	**Timing**	***Stakeholders***	**CGIAR**	***Executive Council***	**Science Council**	***System Office***	**Centres and Challenge Programmes**
Planning Context	5 Years	Collaborate	Approval	Oversight	Prepare	Facilitate	Collaborate
Planning Guidance	3 – 5 years	Collaborate	Approval	Oversight	Collaborate	Prepare	Collaborate
Medium Term Plans **i] Periodic** **ii] Project Portfolio**	Rolling 3years as required	Collaborate Collaborate	Approval	Oversight Approval	Review of Science	Consolidate Consolidate	Prepare Prepare
Annual Operating Plan						Consolidate	Prepare and Approve
Annual Financing Plans	October		Approval	Oversight		Consolidate	Prepare
Evaluation & Impact Assessment	Periodic	Collaborate	Decision	Oversight, follow-up	Commission (programme atic)	Commission (manage-ment)	Collaborate
Annual Ex-post Report	April			Oversight		Consolidate	Prepare

[15] From Attachment 1, Functions of the CGIAR Executive Council (ExCo), CGIAR AGM2001, Washington.

AGM'01 Summary Record of Discussions and Decisions on the Science Council (SC)

Recommendations 7, 8, and 9 which covered the transformation of TAC into a Science Council of eight members plus the Chair were considered together. The recommendations were endorsed on the basis of comments, clarifications, and modifications. There was general agreement that the transformation should be carefully managed, and that a working group should be created by the ExCo to prepare a detailed proposal, including composition, functions, alignment with ExCo and the System Office, costs, and operational and administrative aspects of the transition. The size of the SC was discussed, as well, with some members suggesting that it should eventually be set at a maximum of twelve, with balance and diversity.

The need for the SC to draw on international networks of scientists was reiterated, and it was suggested that the range of skills of SC members should be kept under review. Quality, perspective, and diversity were considered as essential criteria applicable to the Science Council. Science management, some members felt, should be added to the core competencies of the SC, and different forms of science including traditional knowledge should be part of the council's skills mix. There was a strong sense expressed that resource allocation related to key programmatic matters should be among the topics on which the SC could comment, and that this should be reflected in its terms-of-reference. Peer review should also be a responsibility of the SC. The SC was expected to advise the ExCo's Programme and Finance Committees, and to report to the full CGIAR through the annual general meeting.

Members stressed the importance of ensuring that the regional priority setting work undertaken so far by TAC should be continued, and that a smooth transition from TAC to the SC should be ensured.

Decision 7:

The primary responsibilities of the Science Council will be: (a) to serve as guardian of relevance and quality of science in the CGIAR, and, (b) to advise the CGIAR on strategic scientific issues relevant to the Group's goals and mission. SC should also function as a strategic adviser to ExCo and its Programme and Finance Committees and should ensure that a system of peer reviews is in place across the System. The functions of SC are described in Attachment 5, and its roles and responsibilities in relation to CPs are described in Attachment 4.

Decision 8:

The SC will be composed of up to eight (8) individuals plus the Chair. The members should be eminent scientists in relevant disciplines in the biological, physical, and social sciences. While solid scientific stature should be a major selection criterion, the members of the Council should have strong science policy and development experience, with the overall composition of the Council reflecting diversity in forms of science and

understanding of science management. The size and the range of skills required of SC members should be kept under review by the ExCo.

Decision 9:

The SC and its Secretariat should have its operational costs covered by the Cosponsors and should be hosted by FAO. An agreement among cosponsors covering the terms of FAO's hosting of the SC Secretariat should be prepared and formalized. This agreement should cover, among others, an institutional arrangement permitting greater latitude to the SC in recruitment of staff and provision of services to SC members while satisfying any legal obligations of FAO as host organization.

The present TAC should be phased out as of December 31, 2001, and an interim SC should be constituted at the beginning of 2002, when the transition from the TAC Secretariat to SC Secretariat would commence. The ExCo should establish a working group to prepare a detailed proposal on the SC's composition, functions, alignments with the CGIAR's governance units, and operational, and administrative aspects of the transition from TAC to the SC, including its cost structure and mechanisms of financing, in the context of the broad decisions taken by the CGIAR at AGM2001. The transition arrangements recommended by the Science Council Task Force (described in Attachment 5) should be considered as background for the ExCo working group.

Essential Features of the Three Main Programmatic

Modalities in the CGIAR

Centre Core Programmes:

- All research and research-related activities as approved by their respective Centre Boards, may include regular inter-Centre collaborative activities that are normally reflected in the individual Centre report of activities and budgets.

- Conceptualization, *ex-ante* peer review, approval, implementation, monitoring and evaluation and impact assessment under Centre-managed processes.

- Periodic external evaluation by the *Science Council***.**

Systemwide Programmes:

- Research and research-related activities requiring inter-Centre collaboration for more effective and efficient implementation; mainly involving the Centres and their NARS partners but may also involve other non-CGIAR entities.

- Formally approved, recognised and funded as such by the CGIAR.

- Includes facilitation and co-ordination activities plus new activities beyond the Centre core programmes, which provide clear value added to the totality of CGIAR System activities in the topic/problem area (e.g. SINGER in the Systemwide Genetic Resources Programme).

- Managed by a *Lead Centre*/convenor on behalf of the CGIAR and the partner institutions; through a Scientific *Steering Committee* (or equivalent) with representatives from among the partners institutions to provide coherence, cohesion, direction, priorities.

- Members of Scientific *Steering Committee* are recognized practitioners in their specializations; need continuity and empowered with adequate authority by the Centres to promote decision making and implementation.

- Led by a SWP leader (director, co-ordinator, etc.) selected by the *Steering Committee* and appointed by the *Lead Centre* empowered by partners and *Lead Centre* to make certain levels of decisions on behalf of the SWP[16].

- For larger SWPs and/or those with broad participation from non-CGIAR stakeholders, a more formal governance entity (a Stakeholder Board) may be more appropriate; need to balance additional transaction costs with perceived benefits.

[16] There is a need for greater clarity in the governance and reporting channels for these programmes to permit adequate scientific monitoring and evaluation.

- Internal research planning, *ex-ante* peer review, monitoring and evaluation and impact assessment by Scientific *Steering Committee*.

- Periodic external evaluation by the *Science Council*.

Challenge Programmes:

- Research and research-related activities requiring inter-centre collaboration and significant external CGIAR partnerships for more effective and efficient research planning and implementation, and adoption for impact.

- Formally approved, recognised and funded as such by the CGIAR.

- Clear specific objectives, milestones and deliverables, fixed time horizons and assured minimum levels of budget and other resources.

- Governed and managed on behalf of the CGIAR and partner institutions by a *Stakeholder Board*.

- Led by a CP Director with fixed appointment, responsible to the *Stakeholder Board*.

- Assisted by a Scientific *Steering Committee*.

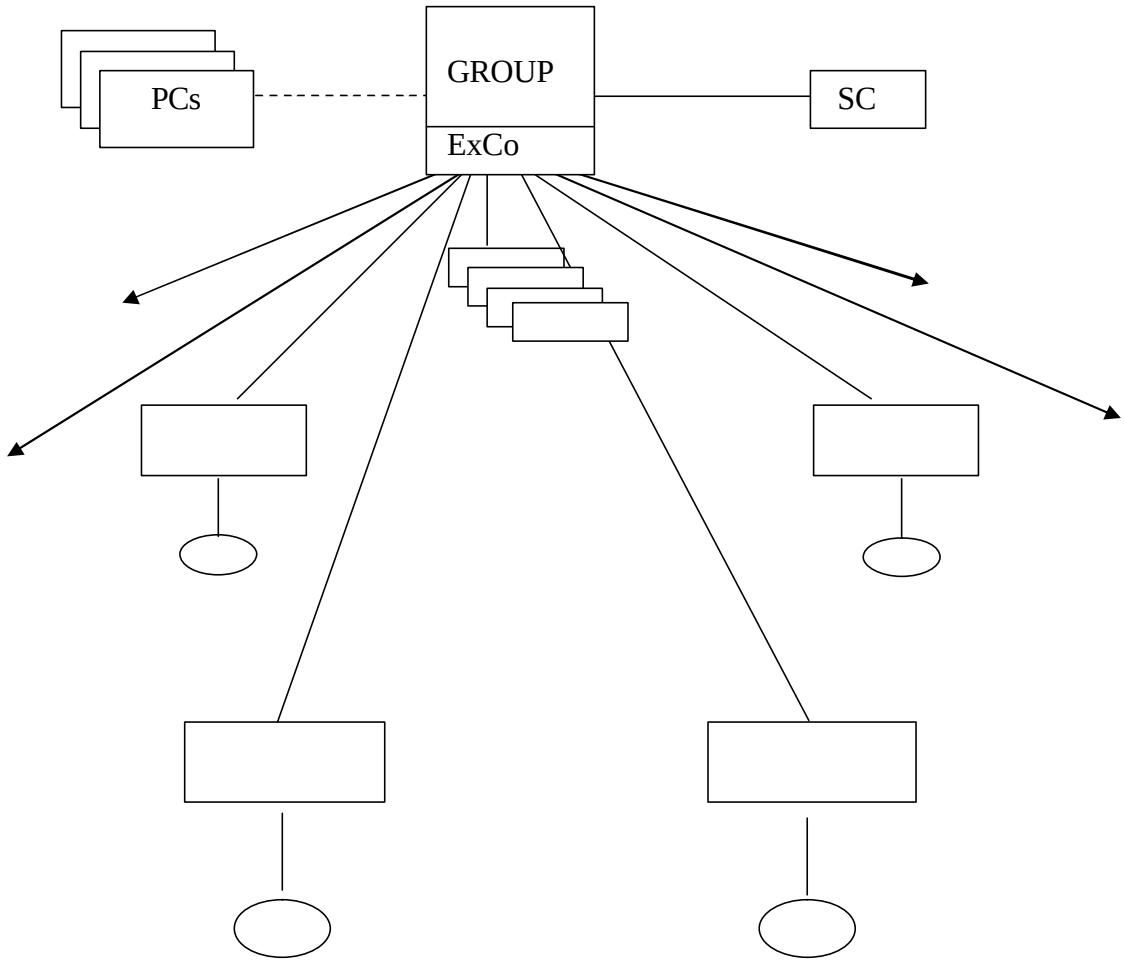
- Internal research planning, *ex-ante* peer review, monitoring and evaluation and impact assessment byScientific *Steering Committee* and *Stakeholder Board*.

- Periodic external evaluation by the *Science Council*.

Table 1: Overview of Suggested Functions of the Science Council in the overall Context of CGIAR Activity and Organization

CGIAR Processes	Context	Role of CG Entities other than the SC	Complementary Role of SC
Research planning and strategy development	Outcomes should depend on: ➢ external science and development environment ➢ comparative advantage	ExCo decision at System level and centres at centre level	SC provides input and advises on appropriate strategy and overall System planning to assure quality and relevance of research;
Organizing research	CGIAR research organized in Centre Core Programmes, inter-Centre Systemwide Programmes and Challenge Programmes working closely with outside partners	Centres sort out their mix of involvement with different organizing mechanisms	➢ SC is centrally involved in competitive process for CPs and in organizing and shaping the SWPs; ➢ SC provides advice on centre MTPs and other plans;
Implementing, monitoring and evaluating research (incl. Management and governance)	Centres face budget and resource issues; partnership issues, etc.	➢ Primarily centre function to produce outputs; ➢ Centres perform internal M&E, incl.peer reviews; ➢ CCERs; ➢ ExCo through SO monitors and evaluates management and governance, including board performance	➢ SC manages and provides oversight to M&E process to assure quality and relevance of science; ➢ SC performs external reviews as needed; ➢ SC supports Systemwide data base on centre and System outputs, performance, etc.
Impacting poverty, environment and food security;	Where CGIAR activity becomes relevant to its goals	➢ Centres measure impact of their activities; ➢ ExCo monitors centre impacts for CGIAR members	➢ SC performs impact assessment at System level; ➢ SC supports Systemwide data base and information centre for impacts;
Feedback into planning and strategy	Creating the dynamics of the CGIAR System; learning by doing	Centres do this at Centre level, feeding information to System;	SC does this through its continuing planning processes

Figure 1: Organizational Design of the CGIAR



Inner core of Centres (16)
Outer Network of Challenge Programmes
Subsidiary Network of Systemwide Programmes
Formal reporting responsibilities
Co-ordinating, advising relationships
(Centres, CPs and SWPs are interconnected by multiple dotted lines, not shown in order not to clutter diagram)

GROUP - Donor/member (58)
EXCO - Subset of Group (21)
SC - Science Council
PCs - Partnership committees and others

Water and the CGIAR: A Discussion Paper

By Elias Fereres and Amir Kassam

SDR/TAC:IAR/01/23A Rev.3
iSC Working Document

CONSULTATIVE GROUP ON INTERNATIONAL AGRICULTURAL RESEARCH

Interim SCIENCE COUNCIL

Water and the CGIAR: A Discussion Paper

iSC SECRETARIAT

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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WATER AND THE CGIAR:
A Discussion Paper[1]

1. Introduction: Purpose and Scope

This paper has been prepared with three objectives in mind; first, to inform CGIAR stakeholders of the current state of water in the context of CGIAR activities and of the needs, challenges and opportunities for water research in the CGIAR. A second objective is to identify the most relevant issues and goals to be pursued in research by the CGIAR, given the complexity of water problems, the probable future scenarios, and the comparative advantages of CGIAR Centres. Finally, a vision for the future and the elements of a research agenda on water for the CGIAR, including possible roles of the various Centres in this area, are presented. The overall aim of the paper is to facilitate discussions towards the formulation of a common strategy for water research in the context of CGIAR's comparative advantage and the evolving CGIAR framework for integrated natural resources management.[2]

This effort is justified by the perception that water scarcity worldwide will be a problem of increasing importance in the 21st Century and could affect directly the main objectives of the CGIAR, namely, poverty alleviation and sustainable food security. Failure to resolve the many conflicts related to water in the past, from local to international, indicates that renewed and well coordinated Systemwide research efforts will be needed to ensure adequate water supplies, healthy aquatic ecosystems and efficient use of water. These are but a few of the many goals encompassing the rational management of water resources in the future.

The paper presents first an introductory section on water management principles to delineate a framework of the water problem and to outline the role of management in achieving an efficient use of a scarce resource such as water. This is followed by a brief outline of the world water situation and of probable future scenarios. A section on major water issues, problems and opportunities in research, particularly in the context of CGIAR activities, is then presented, followed by the section on the vision for research in water management in the CGIAR.

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[1] Discussion working paper prepared by Elias Fereres and Amir Kassam. An earlier draft version of the paper was discussed at TAC 81 in September 2001 at CIFOR. A revised draft of the paper was distributed for comments to all CGIAR Centres. Their comments were incorporated in the subsequent draft which was discussed at iSC/TAC 82 in April 2002 at CIP. This final draft incorporates comments from iSC/TAC 82. The review comments from the Centres are gratefully acknowledged. Special appreciation is expressed to Hans Gregersen, John Vercoe, Klaas Jan Beck, Adel El-Beltagy, William Dar, Bekele Shiferaw, Don Pedon, David Molden, Ken Fischer, Ruth Mienzen-Dick and Jacob Kijne for their input.

[2] See: (a) TAC (2001a) Evolution of NRM Concepts and activities in the CGIAR. Paper presented at the Workshop on Integrated Natural Resources Management for Sustainable Agriculture, Forestry and Fisheries, 28-31 August 2001, CIAT, Cali, Columbia. SDR/TAC:IAR/01/18, TAC Secretariat, Rome. (b) TAC (2001b) NRM Research in the CGIAR: A Framework for Programme Design and Evaluation. SDR/TAC:IAR/01/24 Rev.1, TAC Secretariat, Rome.

2. Managing Water as a Renewable Resource

2.1 Main Features of the Hydrologic Cycle in relation to Water Management

Freshwater is a very small fraction of all water in the Earth. There are about 100,000 km^3/yr of precipitation of which 60 % evaporates to the atmosphere. Only less than a quarter of the remaining 40,000 km^3 is accessible to man for diversion to various uses.

The urban, industrial, agricultural, and environmental sectors all use water diverted from surface and groundwater sources and storage facilities. Agriculture is the primary user of diverted water; two thirds of all diversions are used for irrigation worldwide. Rainfall in excess of that infiltrating the soil runs off to watercourses and eventually, to the oceans. On land, water evaporates from plant and soil surfaces, driven by solar radiation. Evaporated water condenses to fall as rain elsewhere, closing the hydrologic cycle.

In any watershed, incoming water in the form of rain or irrigation must be balanced by evaporation from soils (E) and transpiration (T) from plants (termed evapotranspiration, ET) plus that moving out as runoff, deep percolation and the stored soil water. It is possible to quantify a water balance at many scales, from an individual field, to a farm, a hydrologic basin or a region, up to the global scale.

Water that evaporates from a watershed is considered a loss or consumption, while water running off can be recovered downstream and may not be lost to the system. Thus, there are consumptive and non-consumptive uses of water. Water applied as irrigation may be used consumptively in the ET process, while the network and runoff losses may be recovered downstream and used by others.

Water used within a basin is not always consumed in that basin and can be used several times before it leaves the basin. Water conservation efforts may or may not lead to net water savings depending on whether the water saved is part of the recoverable or the unrecoverable losses.

Every time water is used, its solute load increases as of course does the chance of it picking up contaminants; the result is a deterioration of water quality. Such deterioration has many and diverse impacts, from human health to ecosystem services, and it directly affects the availability of water supply for many uses.

2.2 Management of Water for Agriculture and the Environment

Crop plants loose large amounts of water, keeping less than one percent of what they transport from the soil to the atmosphere during their life cycle. Crop consumptive use is met by stored soil water from rainfall and/or irrigation.

When soil water supply is insufficient to meet the evaporative demand, crops undergo water stress and their production levels are usually reduced. Irrigation is aimed at avoiding water stress in periods of insufficient rainfall, although often the irrigation supply is insufficient to fully meet the crop demand.

Effective water management in rainfed and irrigated agriculture has very similar goals: maximizing the use of stored soil water and at minimizing losses to runoff and percolation. There is no reason to isolate rainfed from irrigated agriculture, since in many agricultural systems a continuum exists from rainfed to limited to full irrigation supply.

Lack of control of runoff and percolation losses in agriculture leads to a major source of non-point pollution that negatively affects the environment. While some losses may be unavoidable, effective water management is the primary tool to minimize pollution from agricultural systems. Therefore, environmental impacts of agriculture are directly tied to water management.

Irrigated agriculture is often seen as a water source for alternative uses, given the large proportion of the diverted water that is used for irrigation. Irrigated agriculture can play an important role in mitigating water scarcity if integrative, coordinated approaches to water management are pursued at the basin and regional levels.

Water plays a critical role in supporting environmental services and, therefore, environmental water use should not be considered in isolation from other uses, including agriculture. There is insufficient information on environmental needs and on the functioning of many aquatic ecosystems, in particular those that have been altered by intensive water development. This is one reason why environmental demands have been a source of conflict among water users.

Management of these competing demands is also constrained by the absence of governance systems that allow for equitable sharing of the benefits of water use, whether this be for agriculture or maintenance of ecosystem benefits. Such governance systems need to be developed and provided with accurate information on the nature and distribution of the benefits of different forms of water use.

A number of new approaches in water and watershed management are directly relevant to the effective and efficient management of water resources for agriculture, environment, domestic consumption and industrial uses. Unless realistic options for significant importation of water exist, management of water resources at the watershed level and in an integrated fashion becomes a necessity, since there are competing uses for water as it flows through watersheds or catchments and river basins. Watershed management becomes one way to focus integrated natural resources management, when water is the main scarce resource of concern. The key to effective watershed management is development of institutional mechanisms that allow the different stakeholders in a watershed or catchment to effectively work together towards some common goals and targets. Thus, institutional issues become key in effective water management.

3. The World Water Situation

There is general agreement that population increase and economic growth, coupled with mounting awareness of the wider benefits that people obtain from water dependent ecosystems, are subjecting existing freshwater resources to considerable pressures today, and there is no question that the demands for this resource will increase significantly in the future. Thus, there is a generalized perception that water scarcity will be a major problem worldwide as we progress into the twenty-first century and that inadequate and uncertain supplies will be the norm rather than the exception in the future. The water scarcity problem has many dimensions. While there is physical scarcity in some countries and regions, there is also economic scarcity in many others, where lack of financial resources limit access to sufficient amounts of high-quality water. While statistics vary, there is evidence that in many developing countries, sections of the population do not have access to safe running water, which is essential for a healthy life and perhaps the most basic food of all.

In the past, society responded to water scarcity by developing new supplies. That is not possible in many cases today, as the economic and environmental costs of new water developments exceed either the value of the new resource or the investment capacity of those demanding more resources. The alternative to new developments is conservation of existing resources for which a new conservation ethic is needed in all sectors of society. Agriculture as the primary user of diverted water is under close scrutiny. The combination of high water demands and apparent lack of control makes this sector particularly vulnerable to criticism, and the first to be looked at for conservation and redistribution of water in situations of scarcity. In fact, reallocation of water from agriculture to other sectors has already started in many areas, in particular as urban development continues at an accelerated rate and is expected to increase in the future. However, the role that irrigation plays in sustaining world food production may place a limit to the release of water from the agricultural sector. Opinions vary on the future water demands of the various sectors which no doubt will be an increasing source of conflict as competition for the scarce resource increases. Attempts to resolve these conflicts will need to recognise that the benefits of the different scenarios and their outcomes will vary greatly depending on the reliance of poor rural households upon water dependent ecosystems for flood recession agriculture, fisheries, livestock, and other products, and upon the capacity of water development projects to yield sustained increases in agricultural and industrial production that can improve the economic options of the poor.

Pressures on water resources have generated responses of diverse nature. A notable development has been the recent emergence of many international organizations and fora to facilitate discussions, exchanges of information and of viewpoints on many aspects of water. One important organization is the World Water Council, responsible for the organization of the World Water Forum (the most recent event took place in The Hague in 2000 and the next one will take place in Japan in 2003). The Global Water Partnership plays a key role in implementing the visions at the World Water Forums. There are many other organizations at the regional and even global levels, with similar objectives of disseminating ideas and creating awareness on critical issues. The environment created by these organizations will certainly contribute to the resolution of many water conflicts but in itself, is insufficient to solve most water problems. Most water issues have local and site-specific features

that cannot be ignored; thus, general policies must be tailored to specific situations. Much remains to be done to translate broad visions into effective actions at the appropriate levels.

4. Issues and Challenges in Water Research

From the research viewpoint, these are exciting times. For too long, research on water issues has been disjointed, based on traditional disciplinary sciences without crossing boundaries, largely focused on short-term issues, and lacking coordination and cooperation among potential partners. Surface waters were treated separately from ground waters; water quality, independently from water quantity and each sector of users (i.e., agriculture) was ignorant of all the others. This approach to research often led, not surprisingly, to inadequate policies that were not well suited to solve the problems addressed.

A consequence of the research approach described above is that progress in some disciplines has been lagging behind relative to others, and in some cases, they have been largely ignored in much of the research on water issues. It is now evident that research in the social sciences has not contributed sufficiently to the development of new knowledge in the water area, and that the progress made in the biophysical and engineering sciences, have not been matched by that made in social sciences research. Yet, it has been evident for some time that science and technology are just two components of the solution to most water problems, and that the economic, social, institutional, and cultural aspects of water are essential determinants of its use and management. Insufficient research on water institutions is a particularly critical issue, given that in many cases, institutions are obsolete or even non-existent.

Improving the efficiency of water use in all sectors is a major challenge now and in the future, given the scope for improvement that exists; however, such a goal can only be addressed properly when the underlying basis of water use patterns, both consumptive and non-consumptive, is fully researched and characterized. What are the controls and the factors influencing water use? What responses should be expected to changes in supply and demand? How dependent is food production from natural ecosystems on different levels of water flow? It would be particularly critical to know the responses of the different sectors to extreme events such as droughts. Of all sectors, knowledge of factors determining the consumptive use in the agricultural sector is perhaps the most advanced, although much remains to be uncovered, while very little is known of the basic processes underlying environmental water use.

One critical problem worldwide is the lack of reliable hydrologic data, either because of lack of monitoring programs or because many of the programs designed in the past for field data collection have deteriorated. Causes of that deterioration include lack of funding for long-term monitoring programs, diversification of government agencies with overlapping functions and gaps, and the decline in prestige for field activities of routine nature. One result of the inadequate data collection programs is the unreliability and uncertainty of water supplies caused by the lack of precision in hydrologic forecasting. The problem is particularly critical in the developing countries where the absence of data even prevents hydrologic forecasting and rational water

resources planning. (The key question here is – what data do we need to be able to make better decisions).

The last decades have seen a decline in the quality of water due to anthropogenic activities. Surface water quality deteriorated first but now, evidence of the lowering of groundwater quality is becoming apparent in many parts of the world. We need a better understanding of the physical, chemical and biological processes that determine the long-term changes in water quality, particularly in groundwater, which is expected to be an increasingly important source of supply in the future. Thus, there is also an urgent need for developing new strategies for efficient groundwater recharge in different watersheds. Much progress has been made in recent years in the development of simulation models of contaminant transport in soils and water but more efforts are needed in producing means for preventing pollution, in assessing the capacity of environments for processing contaminants, and in predicting impacts of water quality changes at the ecosystem level.

In most environments, the use of water follows a continuum from the initial efforts in water development to the competing demands for an increasingly scarce resource. Solutions to the water crisis require multidimensional approaches including supply augmentation, demand management and enabling policy and institutional options. The exact combination of strategies will differ among locations and regions, as most water problems have many site-specific features. Research aimed at identifying what interventions will likely have the greatest relevance under varying biophysical, socioeconomic and cultural conditions, will be critical in focusing the correct solutions to water problems.

Many more research challenges could be listed but regardless of the problem tackled, what is most important is to approach it with the correct framework and focus. It is time to consider simultaneously water quantity and quality; to analyse jointly surface and groundwater; to bring into the analysis at the start, all the social, environmental, and health components that are relevant to the problem under consideration. To summarize, it would be hard to find an area of research where multidisciplinary approaches would be more effective that they can be in the area of water.

5. Research on water in the CGIAR

In the present climate, what are the major water issues relevant to CGIAR goals? The CGIAR has certain comparative advantages in carrying work in water at the various scales, from the farm up to global, that should be offered to the international community. Actually, recent initiatives at the global scale by IWMI highlight the potential of the CGIAR to act as a focal point in some critical issues. Renewed efforts in water research are now undergoing in most, if not all of the other 15 CGIAR Centres. While other international organizations are very active in many international initiatives, the CGIAR is one of the few that could contribute much needed research information in many world areas. The CGIAR must focus more on water in relation to the plight of the poor in particular. There is a need to increase the adaptive capacity of the poor to adapt to, and to manage the water supply and quality constraints. This could be achieved by focusing at the community level and by

developing inexpensive, easy to use monitoring tools that would alert the communities of forthcoming problems and provide them with means to take remedial action. This action is often needed long before there is any hope of changes in policy and other macro-level interventions. The fundamental issue of water as a food requires that attention be given to the quantity and quality of water available for domestic use in poor households and communities. Health issues associated with domestic supply and with irrigation management have been important research themes in the CGIAR and demand increasing attention.

In the future, CGIAR Centres could effectively participate and even coordinate interdisciplinary research on water together with many stakeholders at the national and regional levels. Given the current composition, activities and comparative advantages of the CGIAR, it is proposed that research on water management should focus on the following four broad general areas:

1. Improving the efficiency of water use in agriculture, via increased water productivity;
2. Management of watersheds for multiple functions;
3. Management of aquatic ecosystems, in particular those with boundaries with terrestrial ecosystems;
4. Policy and institutional aspects of water management.

The first area concentrates most of the current efforts on water-related research of several CGIAR Centres and deserves the highest priority because of its direct links with one of the two main objectives of the CGIAR, namely that of sustainable food security. The other three areas have been addressed in the recent past and are emerging as important areas of research for some Centres. In addition, the water Challenge Program uses basins as key units for research development within the program. The CGIAR also has an ongoing, cross centre dialogue on integrated natural resources management. This initiative focuses on several of the four priority areas listed above.

What follows is a justification of the research needs and opportunities as well as some initial ideas for the development of a specific research agenda on each area. As the aim of water management research is to address water constraints and issues in an integrated manner, the four areas cannot be treated in isolation from each other. Instead of listing a fifth area for achieving integration, we refer readers to TAC's views on INRM (see foot note 2).

5.1 Improving the Efficiency of Water Use in Agriculture

Large amounts of water evaporate through crop plants, normally several hundred kg of water per kg of biomass produced; however, the supply of water to agricultural systems is even much more than what ends up consumed in crop transpiration. In some rainfed systems, only 5% of the rainfall or less is consumed as transpiration (T). In irrigated systems, some 30% of the water input are considered normal as transpirational losses. There are, therefore, substantial opportunities to increase the proportion of water that is used consumptively in agricultural systems, thus improving the efficiency of water use. Such opportunities are very diverse and

occur at multiple scales, from plot to farm to watershed and region and at the biological, environmental, and management levels.

As stated above, not all water used in agriculture is lost to the system but can be recovered, at least in part, and reused. Thus, efforts to improve the efficiency of water use may or may not lead to net water savings, depending on whether the water saved is part of the recoverable or the unrecoverable losses. It is therefore important to make such distinction, for which two general ratios are useful in expressing the efficiency of water use for biological production:

Water Use Efficiency (WUE) = Water consumptively used in ET/Water input; and,

Water Productivity (WP) = Yield[3] / Water consumptively used in ET.

Improving WUE by reducing the water input into the plot or the farm may or may not result in an overall improvement for the reasons stated above. Also, some of the influencing factors are related to the physical infrastructures of water delivery and management. As discussed below, research in the CGIAR for improving WUE in agriculture should have a very strong institutional and social component.

The improvement of WP by increasing yield and/or reducing ET, always results in a reduction of agricultural water requirements. This is the reason why David Seckler correctly focused some years ago on improving WP as a fundamental research goal of IWMI. Actually, all the yield improvement research carried out by the CGIAR has made an important contribution to the global increase in agricultural WP experienced over the last decades. In contrast, very little progress has been made in reducing ET, the denominator in the WP ratio.

The challenges and opportunities for future research in improving WP can be discussed around three system components: the **biological** (crop), the **environmental**, and the **management** component. Obviously, it is through synergies among such components that progress in increasing WP has been and will be made.

In the **biological** area, genetic improvement of WP has already been achieved as part of the yield gains effort, particularly in the irrigated systems, and more will be possible as effective demand for biological products continue to improve, allowing farmers to increase yields. Specific breeding programs aimed at improving WP, in rainfed systems, have not been nearly as successful except in the relatively favourable rainfed production systems. Primary reasons in the unfavourable rainfed systems have been the multiplicity of crop responses to drought and the large variability of drought-prone environments. Notwithstanding such difficulties that make short-term progress in drought adaptation a very uncertain proposition, biotechnology offers new possibilities that, combined with the expertise that several CGIAR Centres have in crop adaptation and performance in adverse environments, should open an important avenue for research in the medium term. As an example, one important goal would be to aim at yield stability in low rainfall years in marginal environments in an attempt to produce cultivars that would avoid the catastrophic impact of severe droughts but continue to provide bumper yields in average and good rainfall years. Another

[3] Water productivity can be quantified on the basis of biological output or economic return.

important medium-term research objective of producing a C4-type rice, if achieved, would increase significantly the WP of this major irrigated crop.

The major reason why it has been so difficult to reduce ET is that it is primarily dependent on the evaporative demand of the **environment**. That characteristic cannot be changed easily, but there are opportunities for WP improvement in the temperate zones and in cooler mid and higher altitude tropics and subtropics if crops could be raised when the evaporative demand is lowest; i.e., in winter. However, the primary way to reduce total ET is by growing a crop that has lower water requirements because of its shorter growth cycle. Here, crop choice, environment and management (by selecting optimal planting dates) interact and new research could produce excellent results if modelling is combined with experiments to offer the best strategies that maximize WP and income. As it is the T portion of ET, which determines biological performance, increasing T through rapid or continuous ground cover can lead to higher WP.

There are important effects of the environment in WP. WP in the summer of the arid zones is several times lower than in the winter of mild climates and inside greenhouses. Such differences, together with the opportunities that protected cultivation techniques such as plastic tunnels and unheated greenhouses offer for high WP and high economic returns for small farms, points out at the need for the CGIAR to get involved in horticultural research where appropriate.

The major opportunities that exists today in improving WP and that demand priority efforts reside within the **management** component. Inadequate management is the primary cause of the low WP that exists today in rainfed and irrigated systems. There are also challenges in the biophysical area related to maximizing WP under limited or deficit irrigation. It is very likely that many irrigated areas will not have full supplies in the future and will be forced to use limited supplies in an optimal fashion. Actually, large irrigated areas exist today that were under-designed for political reasons and suffer chronic restrictions in water supply. Research at optimizing a limited amount of water has been carried out in the past, but the new tools of spatial analysis and simulation modelling have much to add to the development of effective tools for advising irrigators in optimal scheduling methods. One other major challenge in rainfed but also, irrigated systems, is the need to maximize the potential for stored soil water in the crop root zone. Water conservation measures that increase the fraction of rainfall that ends up in transpiration need to be developed and tailored to each major system. The major advances in the improvement of WP until now have been achieved by yield increases through improved crop husbandry. A primary issue in this regard is the study of the interactions between soil fertility, plant nutrition and water management, from the plant up to the basin level.

While many of the opportunities discussed above have been partly researched, a major gap exists in most agricultural systems between what is known to increase WP and what is actually applied. This is primarily because there has been little or no involvement of social scientists in the research and extension efforts. Here lies a great opportunity for the CGIAR to link several actors and disciplines in agricultural water management research in the major water-limited agricultural systems of developing countries.

Traditionally, water productivity concepts have been applied mainly to crop production. There is no reason why water productivity concepts could not be defined for application to other uses of water for biological production, e.g., livestock or aquaculture. Demand for milk and meat is expected to double over the next 20 years. This demand needs to be factored into future assessments of water use and productivity. Water productivity in livestock production systems must be characterized in all of its dimensions. In addition further consideration needs to be given to developing a broader approach to water productivity, one that can take account of the different uses of water within the basin. This should in particular integrate food production from aquatic ecosystems.

5.2 Management of Watersheds for Multiple Functions

The CGIAR works in areas where the environment has many functions and provides multiple services for the rural population. Most of those services depend on the correct management of watersheds, which in turn depends on having an understanding of the relationships among watershed components. To develop management strategies, the components, structure and function of the watershed must be known. For the CGIAR Centres working at the watershed, catchment (or whole river basin) level, it is essential to understand the hydrology of the area under study. Hydrologic studies should preferably be conducted at the watershed level rather than following arbitrary geographical boundaries. Such studies at the basin level can form the basis for further analysis at higher scales, such as regional or even global levels, where assessments on water resources and demands are important issues where the CGIAR can make a contribution.

Watershed management will always be carried out by multiple stakeholders at the local level, with more or less public and government participation. The role of the CGIAR in this area is as one of the partners in a multidisciplinary team in the research-to-development continuum, being in charge of tasks placed at the more strategic research levels. In this theme, hydrologic issues must be addressed in the context of human interventions, as property rights, collective action and stakeholders participation play key roles in effective watershed management. Also, as livestock and wildlife play a significant role in watershed and basin hydrology, research efforts on their impact in many ecosystems are needed.

The CGIAR should be in the cutting edge of new approaches based on ITC technologies, such as remote sensing and GIS, to incorporate them into the research related to integrated watershed management, carried out cooperatively with other stakeholders. As an indicative agenda, research in the CGIAR under this topic should primarily focus on:

(a) Development and tests of simulation models at the watershed level; and
(b) Assist in the development of benchmark sites and of new methods for risk assessment and risk management with respect to water supply and use in basins.
(c) Institutional and policy research related to designing optimum institutional arrangements for effective watershed management;

5.3 Management of Aquatic Ecosystems, in particular those with Boundaries with Terrestrial Ecosystems

Research in environmental issues related to water has been largely neglected relative to research in other sectors. As an example, at present it is not known with any degree of accuracy what the water requirements are for many, if not most, of the aquatic environments. In some of the environments in which the CGIAR works, the aquatic environments have boundaries with terrestrial environments, and very complex relationships exist between the two ecosystems that are mostly unknown. It is obvious that knowledge of the hydrologic regime would be essential for the understanding of the role of water in those environments. Other important aspects such as the preservation of biodiversity or the assessment of the fate of contaminants in these ecosystems are but two examples of the urgent need to invest more resources in this area.

An agenda for research in this area would have numerous topics, including the following:

(a) Characterization of the functioning of the aquatic ecosystems where the CGIAR works.
(b) Development of simulation models with hydrologic, biological and geochemical components to elucidate the behaviour of such ecosystems and to propose strategies for improved management.
(c) Relationships between water quantity, quality and the provision of services by aquatic ecosystems.

In addressing these topics particular attention should be given to the fish production of aquatic ecosystems. These sustain important capture fisheries in most developing countries and are the principal source of animal protein to many millions of people.

Finally, it must be emphasized that, particularly in the last three areas described in section 5.2, 5.3 and 5.4, it could not be conceived that a research programme could be conducted by the CGIAR without crossing disciplines and even institutions, with broad participation of a wide range of stakeholders, and with a multiple national/international partnerships.

5.4 Policy and Institutional Aspects of Water Management

The urgent need for renewed research on water policy and institutions has been mentioned above as one critical area requiring enhancing research related to water in the social sciences. The CGIAR has the potential to make significant contributions in this area for two reasons; it can freely exchange information and compare features of institutions in the various areas, and it can act as a more objective advisor when policy and management research is carried out on institutional development and change. In general, very little is known about the reasons for the adoption gaps that are so common in agricultural water management. The assumption that new technologies will be picked up spontaneously by farmers is incorrect, and insufficient attention has been paid to the dissemination of appropriate technologies. New knowledge on the different user-organized water institutions must be developed

to remove a critical constraint in many areas where innovative water institutions could make the most important contribution to improved water management. There are multiple aspects integrating biophysical and socio-economic issues that could be covered in this area of research and, given the limited resources, priority should be given to in-depth assessments of the benefits of the research prior to launching the projects.

In the specific area of water and forests, policy decisions are often based on insufficient scientific evidence on the interactions between forests and water issues. Thus, there is a need for further characterization of the causal relationships that form the basis for the policy interventions that will ensure the delivery of expected water services by forests.

Given that many important social science research issues have not been investigated sufficiently, work in this area could explore broad areas of water economics, law, anthropology and other social sciences. In the specific area of water institutions, the research agenda should address:

(a) Innovative institutions that would deal effectively with new problems such as equitable groundwater and waste water management.
(b) Comparative studies of institutions, exploring the cultural, ethical, and religious features of the different entities.
(c) The roles of prices, markets and regulations in improving water management
(d) New methods for enhancing stakeholder participation in institutions and in defining water policies.

6. Concluding Remarks

This discussion working paper provided a basis to initiate a debate in TAC/iSC and with the CGIAR Centres and other stakeholders within and outside the CGIAR regarding the role of the CGIAR in the water sector, the elements of an overall common CGIAR strategy for water management research, and CGIAR's scientific advocacy role in the international arena.

Sustainable food security is inextricably linked with sustainable water security. Progress in achieving improvements in food and water security would depend on integrated NRM approaches for improving water productivity for food, livelihoods and environment. This paper has highlighted some of the key problems and opportunities the CGIAR must address through a coherent Systemwide strategy to achieve sustainable and balanced progress.

This revised document serve as a framework delineating a common CGIAR strategy for water management research and advocacy. The iSC is pleased that the proponents of the Challenge Programme on Water and Food found this framework useful in designing the Programme.

The paper is being shared with CGIAR stakeholders with the iSC Chair's report for information and comments.

Brief Report on the Social Research Conference

by Michael Cernea and Amir Kassam

Draft, 18 September 2002

Brief Note on the Social Research Conference

The Conference took place as planned on September 10-14, 2002 at CIAT. The participants included representatives from 13 CGIAR Centres (sociologists, anthropologists and economists), several internationally reputed social scientists from the Universities in the North and in the South, several national programmes from Asia, Africa and Latin America, one Centre Board Chair, two DGs and one donor (USA).

Ian Johnson's address

After the iSC opening salute, the Conference was tele-addressed live by the CGIAR Chairman. His address was upbeat and excellent, strongly supportive of social research as intrinsic to CGIAR's objectives defined in the new Strategy. As he had just returned from the Johannesburg meeting on sustainable development, he emphasized the need for the CGIAR to conduct research that would produce and deliver technology and knowledge that were socially and environmentally responsible. Participants and Ian engaged in a substantive Q and A exchange, after the address.

Agenda

The Conference made a detailed and documented group analysis of social research as an important component of CGIAR's overall research agenda. The focus was on the status of social research in the System, capacity, issues, achievements, resources, weaknesses, difficulties, understaffing, new tasks. The substance was provided by "Centres' papers", containing a detailed analysis of these issues in Centre after Centre, and together amounting to an analysis better informed than anything we had before on this, and to good institutional learning. Major problems regarding recent decline in capacity, erosion, quality and depletion of intellectual capital, and drop below critical mass in several Centres, were brought up in the papers and discussions. Remarkably, the Conference discussions confirmed and documented in convincing detail the critical signal given to the iSC by virtually all EPMR teams, again and again over the last 3-4 years, about the insufficient social non-economic research in many Centres, while the demands for social analysis are increasing.

Centres' assessments were complemented by valuable papers presented by outside scholars on social research issues relevant to the CGIAR, and by reports on the Census and surveys of CGIAR's social researchers, undertaken by iSC/CIAT and an outside group.

Main messages

Among the main "messages" from the Conference, several of immediate relevance could be summarized as follows:

1. Strong recognition that CGIAR's Strategy 2000 introduces important new tasks and opportunities regarding intensifying farmer-focused social research within the CGIAR -- that must be poverty related, demand driven, problem solving.

2. CGIAR offers important comparative advantages for effective social research: for instance, continuous intra-Centre and intra-System interaction between social researchers and biophysical researchers; options for immediate field-testing; legitimacy and incentives for applied research, more than in many other settings; etc. Various models of integrating biophysical with social research are successfully practiced and encouraged.

3. Within the social sciences themselves, interaction between economists and non-economic social researchers is promoted and is fertile when both are available in the same Centre.

4. When relevant social issues are addressed with quality social science, the results make- and have made- an important difference in the Centres' work.

5. Conference papers reported that the capacity for social research has declined over the last 3-5 years in several CGIAR Centres. This erosion trend in the CGIAR system is manifest in: Decrease in number of social researchers in several Centres; Composition change: decrease in PhD level researchers and increase in below PhD level researchers; Disappearance -- total or near total -- of social researchers, other than economists, in several commodity or natural resource CGIAR Centres; at best, maintenance of prior staff. Some Centres known in the past for the strong presence of social researchers e.g., CIMMYT with some 4-5 anthropologists/sociologists in the past, has now none, only one "human ecologist"; ILRI and ICRISAT have none as well. WARDA, not joining the Conference, has none. Making better use of existing resources can hardly be done when such resources are sub-minimal or totally absent.

6. No single Centre (perhaps one single exception, under verification) has reported any increase in social researchers over the last two years, notwithstanding the emphasis in the new CGIAR Strategy on poverty orientation, participation, and other social variable in research.

7. Several Centres reported a worrisome drop "below critical mass" level. This further diminishes the ability for intellectual influence on the Centres' agenda. Skill-mix impoverishment in Centres negatively affects interdisciplinarity and partnerships. .

8. The Census of social researchers (economists and non-economists), carried out pre-Conference through Centre DGs and iSC/CIAT, reveals the following "human capital" for social research in the System (see Table 1 at the end of the

report containing staffing data Centre by Centre based on a survey and Centres' papers). More facts are provided in the "Centres' papers".

- Economists dominate the social science staff numbers, with economists making up some 60% of the social scientists.

- For every 3.5 economists in CGIAR, there is one sociologist or anthropologist.

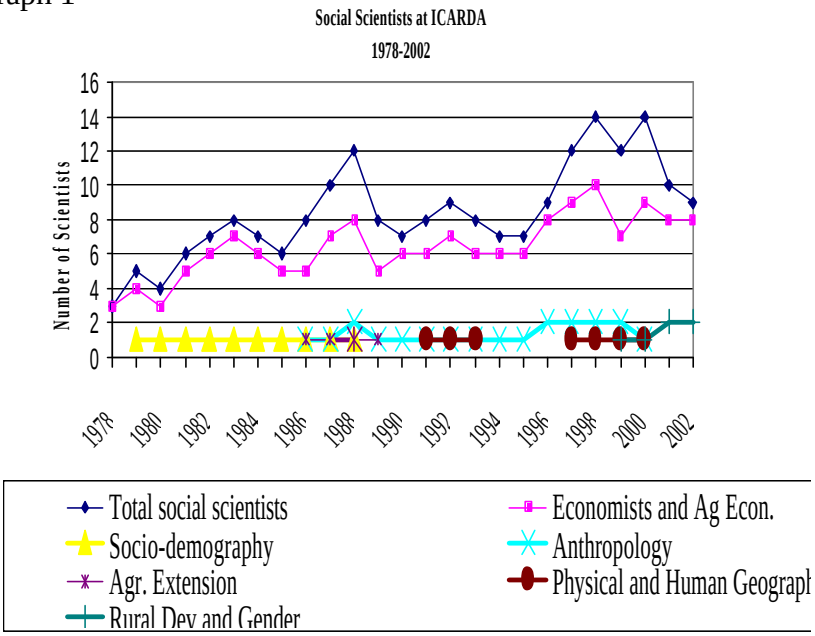
- Some economists undoubtedly have a strong social orientation, but for CGIAR as a specialized research system this is not being seen as a substitute to trained social and cultural professionalism required at science research level.

- Some 27% of the researchers listed by Centres' management as social researchers and included in the survey turned out to be neither sociologists, nor anthropologists, nor economists, yet are considered participants in social research. They only increase the appearance of social research but not its substance.

- Compared with 1995/6, when the TAC-commissioned stripe study of social science was conducted by a panel led by Alain de Janvry, there has been a 24% drop in social science staff numbers in CGIAR while the total number of scientists has increased by 2.2%.

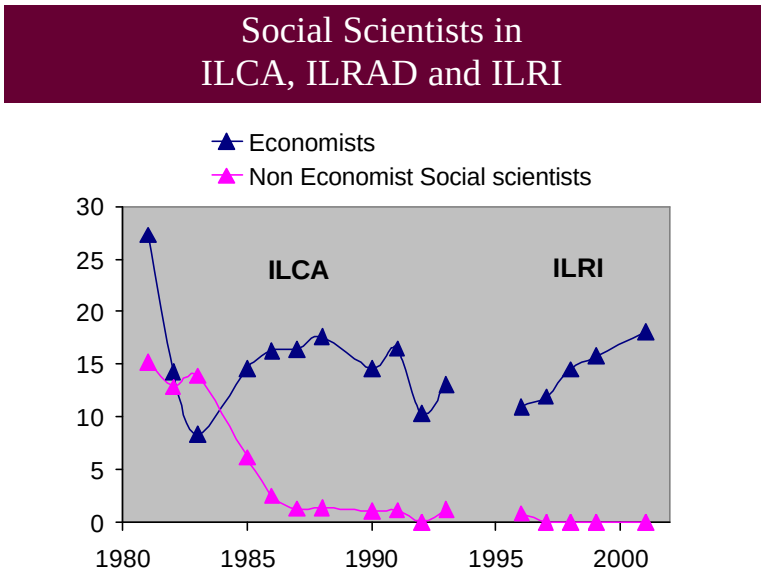
9. Economists from several Centres reported in their papers that they do not have sociological counterparts in their Centre. For example, the attached graphs were presented by participating economists from ICARDA (Graph 1) and ILRI (Graph 2), who pointed out the declining curve, or zero curve, of non-economic researchers in the respective Centres.

Graph 1



Source: ICARDA's paper at the Conference. The graph shows the imbalance between the number of economic and non-economic researchers: the former are four times as numerous as all the later combined.

Graph 2



Source: ILRI's paper at the Conference. There are zero non-economic researchers during the last 5 years. Yet, the distinct and complex social structures, cultural and behavioural characteristics of pastoral populations are crucial to understanding livestock traditional management.

Quality and content of social research

On quality of science and content issues in social research, and the place of such research within the Centres' research strategies, the conference brought up several substantial points:

- Social research has been pushed too much downstream, into ex-post impact assessments, at the expense of upstream knowledge generation for inclusion in, and guidance of, integrated research programmes.

- Service research often takes precedence over strategic research. One sociologist in the Conference defined this trend colourfully: "I am told to go out to find answers for other researchers' questions, not to raise research questions myself."

- There are very few self-standing social research projects (good examples are CAPRi and PRGA, not multiplied though in recent years); the potential for research on other priority CGIAR social, cultural, and behavioural issues is not fully appreciated and exploited.

- Social researchers report little involvement in the definition of, and decision making about, Centres' research priorities.

- Centres' papers reported no initiative by their DGs/Boards, over last 2 years, for adjusting Centres' skill-mix consistent with the new CGIAR priorities and strategy.

- Indigenous knowledge and practices, always proven as a valuable resource for breeders and other bio-physical scientists, are insufficiently explored.

- Focused research on participation has clearly gained in the CGIAR, with multiplier improvements in the methodologies of biophysical research. Yet genuine participatory research is often replaced with rhetorical/broad-brush "participatory painting" at the surface of research programs, in the absence of specialized socio-cultural skills for substantive research.

Strategic directions for social research in CGIAR

Considerable discussion in the conference focused on identifying the most important topical directions for social research to respond to CGIAR's objectives and to exploit CGIAR's distinct comparative advantages for social research. The Conference identified at least seven major areas of opportunities for social science research that would contribute to implementing the new CGIAR strategy and increase impact.

- Sharpen the poverty lens and focus of social research in CGIAR.

- Promote culturally informed methodologies in CGIAR's biophysical, technological, and policy research.

- Study the implementation of innovations.

- Carry out organizational and institutional analysis, promote institutional learning.
- Build and manage new partnerships in research.

- Study how policy and power relations affect technology adoption by farmers.

- Research social impact of CGIAR's outputs.

The planks of CGIAR's new Vision and Strategy statement came up in papers and discussions. The CGIAR Strategy document clearly defines an important social research agenda for CGIAR, for all its planks, and this agenda was supported in papers, plenary, and working group discussions. However, there was a clear consensus in the Conference that the opportunities opened up by the new CGIAR Strategy and Vision document cannot be met adequately by the existing very limited social research capacity in various Centres and the CG system at large. Expectations were expressed that the ExCom will pay attention to the Conference's Report, will examine the recent decrease and erosion in social research and will provide guidance to Centres for arresting and reversing this trend that weakens capacity. Similarly, the Conference expects that the ISC, the DGs of all Centres and the Boards, will also carefully consider the analysis and the recommendations of the Conference in light of each Centre's mandate and need, and will adopt measures both for the better use of existing social research resources and for strengthening them, to match the new tasks defined by the CGIAR's Strategy. These strategic directions for social research as a component of CGIAR's overall research agenda, as emphasized in the Strategy document, aim to reach the following specific objectives:

- Improved socioeconomic understanding of individual, household and community behaviour, considering the heterogeneity of actors and their differentiated demands and potential for technological and institutional innovations.

- Clarifying the extent and location of poverty, its causes, vulnerabilities, risks of further impoverishment and resulting needs, within the specific target populations and agro ecosystems of each CG Centre.

- Integrating poverty mapping with farming systems mapping, spatially and with relation to markets, using GIS and other research tools, to increase the responsiveness of biophysical research to the locations of the poorest farmers and to the issues related to their cropping and farming systems.

- Intensify the study of efficient patterns of social organization for better use and sustainable management of key natural resources. water, soil, trees. Study collective action patterns, gender, and participation.

- Analyzing policy-triggered adverse or constraining effects on productive rural populations, and researching improved policy options and solutions.

- Improved use of social research conceptual and methodological advances to develop knowledge usable in the fight against the varied causes of poverty and asset less; i.e., capitalize on new advances in biotechnology, production ecology, precision farming, geographical information systems, and participatory breeding and extension technique.

Given the current declining trend in social research capacity in the CGIAR, the following were some of the Conference recommendations. (The list is longer. Many are very specific; we continue to work on extracting them from Conference notes and listing them in a clear format).

Some main emerging recommendations

- The new CGIAR strategy and the enabling seven planks call for a critical review of the existing potential of social research within the CGIAR. Socially and environmentally responsible research must integrate biophysical and social sciences at all stages of the technological research from *ex-ante* needs analysis and interdisciplinary research to product delivery and *ex-post* impact assessment.

- Having endorsed the new CGIAR vision and strategy, the CGIAR Donors, Centre Boards and Directors General could discuss this report and proactively facilitate changes in the culture and skill-mix of the CGIAR, management and governance bodies, to strengthen and sustain a strong social science intellectual research capacity.

- There is a need for the Boards and senior management to raise the status of social research in the CGIAR by institutionalizing the role and functions of social research in each Centre, making adequate budgetary provision for interdisciplinary social research based on Centre policy, and providing opportunities to social researchers for strategic research and for resource mobilization.

- There is a need to change the mind-set in many CGIAR Centres, and proactive efforts need to be made to alter values that are not supportive of social research. This requires that Board membership include social researchers, and that social research should be explicitly included in the development of research proposals from the very beginning and proposals are peer reviewed by eminent social researchers along with all traditional disciplines.

- There is large potential for integrating social research into the CGIAR agenda not only in core programmes, but also in Systemwide Programmes and Challenge Programmes. These opportunities should be seized in every single CP and SWP, and System's commitment can best be demonstrated by visibly placing social research within the core, Systemwide and Challenge Programmes.

- Each Centre Board and management must formulate a clear position regarding social research within the Centre. This should include establishing and safeguarding the critical mass for social science research and social research competence, and managing an effective balance between the service research function of social researchers and the longer term social research topics.

- In particular, there is a need for a more effective balance between economic and non-economic social scientists is needed, as recommended by virtually all TAC-commissioned external reviews since 1995, often without consistent follow-up from reviewed centres. Future social science research skills will need to include disciplines such as political sciences, social health, law, history etc.

- Social research must regain its prestige within the Centre and be put into a position to deliver cutting-edge products. This concerns two professional groups within the Centre: social scientists and non-social scientists doing social research. In order to ensure quality research, the training of non-social scientists in social science research methodology is indispensable and of high priority.

- Social researchers themselves must take a lead role in this process of institutional learning and change. They should lead participatory reflection groups liaising and sharing by networking between Centres.

- Social scientists must be given the opportunity to upgrade their knowledge and competence through sabbaticals, exchange programmes, write-shops, etc. The decline in the number of social scientists and in numbers of social scientists holding PhDs must be reversed.

- Promote/help the strengthening of social research capacity (alongside biophysical research capacity) in NARS, which are extremely weak in this area. Adaptation and adoption research has been neglected, while remaining indispensable for better communication and dissemination. CGIAR social researcher may provide a more substantial contribution to developing relevant social research in NARS.

- Based on the very successful Rockefeller Foundation programme to place post-doc anthropologists and sociologists in the CGIAR Centres, which functioned for some 20 years but was not mainstreamed at its completion, it is recommended that a group of donors under Rockefeller Foundation's leadership consider cosponsoring a new comparable programme with provision for mainstreaming successful post-docs as IRS social research staff.

- There is a need for more effective networking with the broader social research academic communities outside CGIAR as well as with NGOs and the private sector which has a potential for tapping additional social research resources, e.g., financing scholarships and exchange programmes as well as research.

- Information exchange, both at System and Centre level should be improved by conducting annual meetings, establishing an electronic newsletter, and creating a social research database of people, topics and projects.

- The exchange of social scientists between universities and the CGIAR System should be intensified at relatively low cost. Conditions be created which allow both junior and senior research staff to join universities and university staff to join Centre research projects for 1-2 years.

- Ensuring excellence of social research must also be a concern at the System level. Some restricted resources should be provided at the System level to finance 2-3 visiting senior researchers per year as well as the establishment of social research partnership between NARS, ARIs, NGOs, universities in the North and South, and the private sector. System management should strongly encourage and reward Centre exchange and networking activities.

- The Science Council should ensure that the external evaluation process and the future *ex-ante* peer review mechanisms to be introduced in CGIAR pay attention to evaluating the presence of relevant sociocultural variables in research programmes and themes. In order to ensure reputation and quality of CGIAR social research, external review processes must include distinguished social scientists from outside the System.

- The Science Council should commission a strategic stripe review of social research in the CGIAR System to deepen the critical analysis of priorities and strategies, and assess further on Centre by Centre basis potentials, needs and work patterns.

Table 1: Social Research Conference
IRS/NRS Survey Tables*

Total Social Science Staff by Center					
Center	Economics	Sociologists & Anthropologists	Related fields	Other	Total
CIAT	2 29% 2%	4 57% 16%		1 14% 5%	7 100% 5%
CIFOR	2 25% 2%	2 25% 8%	2 25% 12%	2 25% 10%	8 100% 5%
CIMMYT	6 67% 7%	1 11% 4%	2 22% 12%		9 100% 6%
CIP	6 55% 7%	2 18% 8%	2 18% 12%	1 9% 5%	11 100% 7%
ICARDA	2 50% 2%			2 50% 10%	4 100% 3%
ICLARM	5 63% 6%	1 13% 4%		2 25% 10%	8 100% 5%
ICRAF	3 25% 3%	2 17% 8%	1 8% 6%	6 50% 30%	12 100% 8%
ICRISAT	4 67% 5%		1 17% 6%	1 17% 5%	6 100% 4%
IFPRI	28 80% 32%	4 11% 16%	3 9% 18%		35 100% 24%
IITA	3 50% 3%	1 17% 4%	1 17% 6%	1 17% 5%	6 100% 4%
ILRI	7 70% 8%		2 20% 12%	1 10% 5%	10 100% 7%
IPGRI		2 67% 8%		1 33% 5%	3 100% 2%
IRRI	7 78% 8%	1 11% 4%	1 11% 6%		9 100% 6%
ISNAR	6 67% 7%	1 11% 4%	1 11% 6%	1 11% 5%	9 100% 6%
IWMI	3 38% 3%	4 50% 16%		1 13% 5%	8 100% 5%
WARDA	3 75% 3%		1 25% 6%		4 100% 3%
Total	87 58% 100%	25 17% 100%	17 11% 100%	20 13% 100%	149 100% 100%

Social Science IRS by Center				
Economics	Sociologists & Anthropologists	Related fields	Other	Total
1 17% 1%	4 67% 20%		1 17% 6%	6 100% 5%
2 25% 3%	2 25% 10%	2 25% 12%	2 25% 13%	8 100% 7%
5 63% 7%	1 13% 5%	2 25% 12%		8 100% 7%
6 55% 9%	2 18% 10%	2 18% 12%	1 9% 6%	11 100% 9%
2 67% 3%			1 33% 6%	3 100% 2%
1 50% 1%			1 50% 6%	2 100% 2%
3 33% 4%	1 11% 5%	1 11% 6%	4 44% 25%	9 100% 7%
4 67% 6%		1 17% 6%	1 17% 6%	6 100% 5%
23 79% 32%	3 10% 15%	3 10% 18%		29 100% 23%
3 50% 4%	1 17% 5%	1 17% 6%	1 17% 6%	6 100% 5%
5 63% 7%		2 25% 12%	1 13% 6%	8 100% 7%
	1 50% 5%		1 50% 6%	2 100% 2%
4 80% 6%		1 20% 6%		5 100% 4%
6 67% 9%	1 11% 5%	1 11% 6%	1 11% 6%	9 100% 7%
3 38% 4%	4 50% 20%		1 13% 6%	8 100% 7%
3 75% 4%		1 25% 6%		4 100% 3%
71 57% 100%	20 16% 100%	17 14% 100%	16 13% 100%	124 100% 100%

Social Science NRS by Center			
Economics	Sociologists & Anthropologists	Other	Total
1 100% 6%			1 100% 4%
1 100% 6%			1 100% 4%
		1 100% 25%	1 100% 4%
4 67% 25%	1 17% 20%	1 17% 25%	6 100% 24%
	1 33% 20%	2 67% 50%	3 100% 12%
5 83% 31%	1 17% 20%		6 100% 24%
2 100% 13%			2 100% 8%
	1 100% 20%		1 100% 4%
3 75% 19%	1 25% 20%		4 100% 16%
16 64% 100%	5 20% 100%	4 16% 100%	25 100% 100%

*Survey results are based on replies received from the Centres which in some cases may not be from all social scientists. This table is still subject to further work and verification, but the basic proportions are thought to be adequate. Adjustments are likely to be minimal.

Application of Molecular Biology and Genomics to Genetic Enhancement of Crop Tolerance to Abiotic Stress: A Discussion Document

by Mike Gale

SDR/iSC:IAR/02/10 Rev.1
iSC Working Document

CONSULTATIVE GROUP ON INTERNATIONAL AGRICULTURAL RESEARCH

Interim SCIENCE COUNCIL

Applications of Molecular Biology and Genomics to Genetic Enhancement of Crop Tolerance to Abiotic Stress – A Discussion Document

by Mike Gale

iSC SECRETARIAT
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
August 2002

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Summary

Only some 10% of the world's 13 billion ha is farmed, although one third of the total land area is considered as potentially suitable for arable agriculture to some degree. Even so, abiotic stress in one form or another, still limits production on most of the world's 1.4 billion farmed hectares. This is a problem that is not going to go away. For example, yield reductions due to drought stress are already serious, and they will increase. Irrigation will cease to be a practical solution as water becomes scarcer, and the irrigation already in place will continue to lead to yet more soil salinisation. High and low temperatures, acid soils and soils with high levels of metal ions continue to reduce productivity over vast tracts of land and will remain an agricultural challenge for the foreseeable future.

Solutions to the problem will be as diverse as the lands affected. However new, locally adapted and improved varieties will always be a central component in any package of engineering, agricultural management, sociological and political solutions. Moreover in these times of surpluses in developed countries, solutions to the problem of abiotic stress are laid firmly at the door of developing country agriculture. It is here that the most severe stresses are found and here the need for increased food production to feed an increasing population is greatest.

The significance of abiotic stress has not been lost on CGIAR plant breeders. There is considerable work aimed at stress tolerant crop improvement already going ahead. Together with NARS and ARIs, the Centers are working towards an understanding of the genetic and physiological control of tolerance to the key stresses in their regions for their mandate crops, and are beginning to apply the results in breeding programmes. Progress, albeit incremental, is real and demonstrates that the problem is tractable to a genetic approach. In short, breeding is a viable option.

However developments elsewhere tell us that the future will not be the same as the past. Our science is becoming more generic on one hand, and more expensive on the other. The pressure is building for more centralization. The science of abiotic stress resistance in the CGIAR could be the test-bed for a new way of working. Genetics itself is one such area, where a new science is emerging from the masses of DNA sequence and the associated novel and high throughput technologies. This new 'genomics' promises more rapid and more spectacular returns, but with expensive equipment, much of which has a short 'shelf life'. Some of these massively parallel genomics and gene manipulation technologies are already, and with some success, being turned on the abiotic stress tolerance problem in 'model' organisms by researchers at ARIs in developed countries. Some Centers are already tooling-up for plant genomics research. Another development is the discovery of 'synteny', where genome organization has been found to be much more conserved over species than was previously thought. Application of synteny will allow advances in our knowledge about stress tolerance and the underlying genetics to be transferred between crop species. Synteny will similarly allow CGIAR and NARS scientists to apply the array of genomics resources already available in the models arabidopsis and rice to their mandate crops.

However, in order to harness synteny and the new genomics in a cost-effective and efficient manner it will be necessary to develop new ways of doing science. These could involve: more rationalization and centralization and sharing of expensive and rapidly improving technologies; more outsourcing to providers of standard scientific

services and the sharing of skills by assembling multidisciplinary teams and networks in virtual centres that will work on a range of crop species. DNA science and the expensive equipment it begs, is identical for all organisms. Suddenly there is obvious potential for economies of scale in major collaborations.

The time could be right for a full-blooded assault on abiotic stress. Ongoing work shows that the motivation is already there. The question is not whether the work is needed, rather only when, how and what firepower should be brought to bear. A really effective collaboration will involve: the NARS with their germplasm collections, their knowledge of and, access to, stressed agricultural environments, and their plant breeders; ARIs with their experience of technology and model systems; the CGIAR Centers with their comparative advantage with the mandate crops, their collections and their networks to the developing world; and possibly industry as well.

Many of these ideas have already been incorporated in a Global Challenge project, 'Unlocking genetic diversity in crops for the resource poor', and, apart from a recommendation to compile lists of potential alternative crops for use in sub-optimal soils and climates, are not dealt with further at length.

Optimal organization of genomics science within the System is relevant and not dealt with elsewhere. It has become clear that the efficient application of genomics and the provision of genomics services within the CGIAR and for NARS partners will require a co-ordinated approach that is not in place today. This paper looks towards a time when basic genomics resources are available for all the mandated crops, and when all CGIAR and NARS researchers have access to sustainably state-of-the-art genomics platform technologies.

The conclusions are that an increasing amount of work will be outsourced to specialist companies, leading ARIs or other Centers. There will likely be strong financial and infrastructural reasons for centralizing other technologies, possibly micro-arrays today and soon the next generation of high throughput genotyping for marker-aided selection and germplasm characterization. There are also scientific reasons for sharing intellectual resources that are in short supply or unevenly spread around the System, such as bioinformaticists and physiologists. There is an opportunity to cost-effectively appoint a central Genomics Facilitator who will carry out market testing, organize key facilities and link groups of researchers around the System so that we can best exploit the new generic aspects of our science. The existing and active CGIAR Task Force on Genomics, with iSC oversight, will provide an ideal forum to discuss these developments.

The potential application of molecular biology to genetically enhance crop tolerance to abiotic stress – a discussion document.

Introduction

Only some 10% of the world's 13 billion ha is farmed. Apart from urban areas much of the remaining 11.5 billion ha are lands too hostile for any sort of agriculture [1]. Moreover almost all the land that is farmable is under conditions sub-optimal, often to a considerable degree, for plant growth. Alongside losses due to pests and diseases, a further 70% of yield potential has been calculated to be lost to unfavourable physiochemical environments, even in developed agricultures [2].

It is acknowledged that, in order to feed the eight billion mouths we expect by 2030, we will need to double world food production yet again. And we will. One component of that achievement will be the breeding of new varieties of food crops that will both improve yields on land presently being farmed on sub-optimal soils and extend our productive agriculture into lands which are currently barren.

Abiotic stress – extent of the problem

Drought. Unpredictable drought is the single most important factor affecting world food security and the catalyst of the great famines of the past. Moreover, because the world's water supply is fixed, increasing population pressures will ensure that the effects of successive droughts are more severe [3] because competition from industry will increasingly limit the water available for agriculture. Crops are voracious consumers, for example, for paddy rice 5000 l of water is needed to produce 1 kg of grain. At present an unsustainable 70% of the world's water is used for agriculture. By 2025 it is expected that most Asian countries will join those that already have water shortages. Uncertainties over global warming raise yet further concerns.

> Drought stress is a concern for most crops at most Centres for most regions. These include, IITA Cowpea in the Sahel, soybean and tropical maize in the Dry Savanna, ICRISAT Sorghum, pearl millet, chickpea, groundnut and pigeon pea, CIAT Bean in Mexico, C America and NE Brazil, IRRI Rice in Bangladesh, E India, Thailand and Indonesia. CIP, Potatoes in China, India, Southern Africa, Kazakhstan and Afghanistan. CIMMYT, Wheat in C and W Asia and N Africa and maize in sub-Saharan Africa. ICARDA All crops (except faba bean which is only grown under irrigation) in N Africa and Asia. ICRISAT all crops in India and the Sahel.

Salt. Some 380 million ha, almost a third of the area farmed, is affected by salt, and the associated water logging and alkalinity [4]. Sixty million ha are a direct result of over-irrigation, where a raised water table brings underground salt, particularly NaCl, to the surface. It is probable that this agricultural salinisation now

degrades as much land as is put under new irrigation each year. Pressures on water use will ensure that the net productive irrigated land will go negative very soon and that secondary salinisation will become critical in Asia, Africa and S America [5].

> Salt stress is of particular significance for rice. IRRI Coastal salinity in Bangladesh, Orissa, Vietnam, Philippines and inland salinity in the Indogangetic plain and Thailand. ICARDA Secondary salinisation is a problem for all crops in C Asia.

Acid and degraded soils. Some 40% of the world's arable land is associated with acid soils, with pH less than 5, where growth is hindered by high aluminium or manganese content. This is particularly important in S America where some 380 million ha are affected, including almost the whole of the Amazon basin [6]. Other excess metal ion contents reduce the agricultural potential of other soils. For example iron toxicity is a major problem affecting rice production in W Africa.

> Acid soils are a widespread problem. IITA Cowpea and soybean in the humid rain forest. CIAT Bean in Africa and both bean and *Brachairia* in L America. IRRI Rice in Bangladesh, Indonesia and Philippines. CIMMYT maize in L America, SE Asia and Africa. Wheat in CWANA.
>
> Other metal toxicities and deficiencies. IITA Low P for soybean. CIAT Low P for bean and *Brachairia*. IRRI Zn, P deficiency in Bangladesh, Indonesia and the Philippines and Fe deficiency in Sri Lanka and the Philippines. WARDA Fe deficiency is widespread in Africa. CIP Low P in China, Africa and in the Andes.

Low and high temperatures. Temperature also limits the range and production potential of many of our crops, even at tropical latitudes [7]. Occasional and unpredictable periods of low temperature can be devastating to yields. For example, in the Andes 70% of land devoted to potato production is prone to cold stress [6].

> Cold stress is a rice problem for IRRI in Korea and Nepal. CIP, potatoes in the Andes. ICARDA Low temperature tolerance has become a problem associated with the shift from spring to autumn sowing for barley, lentils and chickpeas.
>
> Excessive heat is a problem for cowpea. IITA in the Sahel. CIP, for potatoes in S Asia.

In fact, abiotic stress tolerance, particularly drought, is the priority target trait for most of the CG Centers dealing with crop plants. In the present economic and agricultural climate, with food surpluses in developed countries, the focus of the private sector will continue to be protection from disease and improvements in aspects of quality. Even given the extent of the problem and although abiotic stress is a significant factor for production in developed countries, it is unlikely that genetic

solutions will be actively sought by commercial breeding companies. If the problem is to be tackled at all, abiotic stress tolerance mechanisms and their genetic application in the crops of the developing world will have to be addressed by the public sector working in the developing world.

Gene mapping and marker development for genetic analysis and MAS in breeding

Genetic mapping as a prerequisite to genetic analysis is now part of standard plant breeding. Annex 1 shows clearly that base molecular maps are now available for most of the CGIAR's crops. Those that are the focus of international effort, e.g. rice, wheat, potatoes, can use the well-developed public maps. Base maps for many of the 'orphan crops', in which there is little international trade, have been made at Centers or in Center-ARI collaborations. Only a few very minor mandated species remain unmapped.

The mapping of quantitative traits where there is often little knowledge of the genetic control in advance of the analysis, such as is usually the case with stress tolerance, is usually carried out by 'QTL mapping'. This requires a scan of the genome, with markers every 10 cM or so to identify those regions where segregation of the trait is associated with segregation for the markers. The reason much denser base maps are needed is that only a subset of the available markers will segregate in any single population. These locations are the basis for establishing a marker aided selection (MAS) breeding programme for tolerance and for eventual map-based cloning of the genes underlying the QTLs. Annex 1 shows that key stresses in several crops are already being addressed in this way.

Breeders' markers that are closely linked to the target gene may be derived straight from the base molecular map. Today the ideal marker system will be micro satellites, also known as simple sequence repeats (SSRs), although over the next few years single nucleotide polymorphisms (SNPs), which are more amenable to high throughput methods, will take over as the ideal marker.

For rice, which will soon have the benefit of a full genome sequence, markers will never be a problem again. The sequence has been found to contain some 40,000 SSRs[8] and SNPs and, base pair deletions or insertions indels, are found in unique sequence at a rate of about 1% [9], which works out at about 24 in every gene! However, apart from in the major cereals, an adequate supply of good quality markers for all applications is still a problem for most CGIAR mandate crops. The status of the genetic maps and markers available for the CGIAR crops is outlined in Annex 1.

Genetic and physiological mechanisms that control stress tolerance

The physiological mechanisms underlying crop responses to stress and potential biochemical, physiological and architectural modifications that will allow crops to escape, avoid or tolerate stress are the subject of a vast literature. Two general approaches are taken in relation to varietal improvement, and both have their place. The 'empirical' approach proceeds from genotypic differences associated the

best sources of tolerance in the cultivated crop or its wild relatives. Typically sources of tolerance are identified and then the underlying genetic control is investigated by QTL analysis in lines segregating for high and low tolerance. Although the identification of a predominant causal physiological mechanism is helpful, transfer of the improved trait to an already otherwise adapted variety can proceed simply for selecting for and accumulating 'beneficial' alleles. The second approach is often described as 'ideotype' breeding, in which specific morphologies or physiologies that might be expected to contribute to improved performance under stress are identified in diverse cultivated or wild germplasm and transferred to otherwise adapted varieties. The crossbreeding and, these days, marker-aided pyramiding of the underlying alleles is progressed in the same way in both approaches.

There is already considerable work underway at all CGIAR Centers to improve their mandate crops for stress tolerance. Almost all these breeding projects are being carried out in collaboration with NARS to address the major problems affecting their own agricultures. However many of these projects are crop- or geographical area-specific, even though the target tolerance and the technologies used to address the problem beg a collaborative, pan-stress, pan-crop, pan-Center approach.

For example drought, salt stress and cold temperature stress are all physiologically linked because all three stress environments result in limiting the crops' physiological access to water. Thus many of the strategies for improved tolerance are likely to be multiply applicable. These will include osmotic adjustment in roots and leaves to retain water, erecting hydrophobic barriers in roots and leaves to retain water, and improving aquaporin efficiency to speed water movement in the plant. Although tolerance mechanisms might be expected to overlap, escape or avoidance mechanisms are more likely to be stress specific. For example reducing time to flowering may escape late season drought but will not help in a chronic saline situation. Deeper roots may be able to reach the last of the water in a drought but would only aggravate salt stress where the salt is being brought to the surface by a rising water table.

With this background one would intuitively expect genetic control to be multigenic and complex, but to overlap somewhat in tolerance to the different stresses. This is exactly the situation found. Consider, for example, wheat and barley where the various reported genetic effects regulating responses to drought, salt and cold have been assembled on one comparative chromosome map, Fig 1 [10]. While ten or more QTL s are found for each trait, many overlap so that a few chromosomal

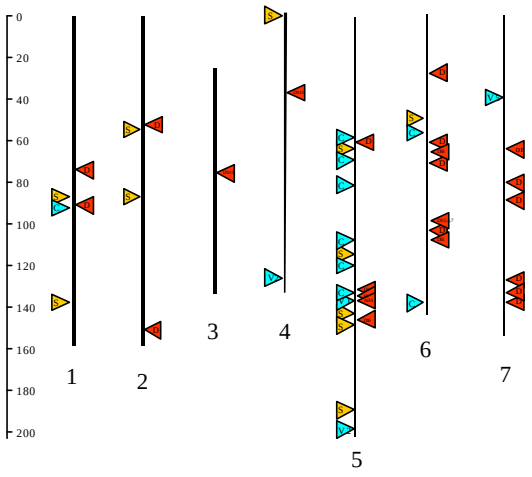


Fig. 1 Abiotic tolerance QTLs and major genes mapped on a composite Triticeae chromosome map. Salt tolerance in orange, cold tolerance in blue, drought tolerance in red.

regions are home to controlling factors for all three traits.

The empirical approach to aluminium tolerance, where the selection screen is usually for improved growth of roots and shoots in Al supplemented nutrient solution at low pH, also reveals complex control. However, the network of genes is often dominated by one locus which accounts for a major proportion of the genetic variation e.g. [11,12]. These results identify MAS breeding priorities and also cry out to be followed by isolation of the key gene, either by cloning or the production of isogenic lines. Gene isolation and knowledge of the gene sequence can be critical steps in a project elucidate an understanding of the underlying mechanism.

A few stress tolerances do usually appear to be under the control of major genes, as revealed by genetic analysis. Submergence tolerance is a prime example, and it may be no coincidence that this trait lends itself to a straightforward and definitive selection screen. This is a key trait in SE Asia where some 25 million ha are prone to flash flooding which can completely submerge the rice crop for several days. Here a single locus, *Sub1*, has been shown to provide substantial tolerance [13,14].

Fig 2 Wheat, *Thinopyrum bessabaricum* (also known as *Agropyrum junceum*) and the man-made amphiploid, Tritipyrum grown in 250 mM NaC1. The amphiploid assumes some of the salt tolerance of the wild maritime grass parent.
From Forster, B.P., Gorham, J.,& Miller, T.E. (1987). Plant Breeding 98:1, p.2, fig 1 "Plants of 'Chinese Spring' amplhiphloid & Ajunceum"

Mention must be made of the potential of wild relatives as potential donors. Wild species, where the *raison d'être* is survival rather than yield, are likely to retain useful variation that may have been bred out of the cultivated crop. There are many examples where genes for tolerance have been identified in wild relatives and have been used to transfer useful variation to cultivated crops. In some cases the wild species themselves have been used directly to create new crop species, e.g. Tritipyrum incorporating salt tolerant *Thinopyrum bessabaricum*, Fig 2[15]. Annex 1 shows that CGIAR breeding programmes are accessing this source of variation. The germplasm collections, which are mostly still relatively uncharacterized, will be central to any future stress tolerance initiative.

A possible alternative to varietal improvement is crop replacement. This is probably a viable socio-economic strategy only in extreme stress environments. Nevertheless NARS and their extension services should have reliable information about those crops which generally perform best in stress environments. These differences are exemplified by investigations into the responses of tropical grasses to aluminium stress. Signalgrass (*Brachairia decumbens*) was found to be far more tolerant than both close relatives and Al-resistant varieties of wheat, triticale and maize [16] Fig 3. It is probable that world-wide multi-centre, multi-crop studies, which are unlikely to be carried out by 'one-crop specialists', might reveal interesting

alternatives in many stress situations, possibly even pushing back the borders of lands presently considered to marginal for agriculture at all. Overall the genetic dissection of stress tolerance for developing countries is receiving considerable attention, particularly in crops that already have advanced genetic maps. Initial understanding of the physiological and genetic controls most certainly informs breeding programmes. Marker-aided pyramiding of several genes is probably the only way forward for the transfer of improved phenotypes that have been shown clearly to be under control of multiple loci. However these methods have yet to impact stress tolerance breeding programmes. Although a few endogenous genes have been identified which are likely to have major beneficial effects when used as a transgene, these have not yet been applied to practical breeding.

> Mapping by NARS and CGIAR Centres has identified a number of genes, usually as anonymous QTLs. Most of these genes have not yet been associated with physiological mechanisms. Linkages between geneticist-breeders and physiologists could now pay dividends. The potential is there for application of these QTLs through MAS but this has not yet been generally successful. There is considerable scope for more collected wild and cultivated germplasm characterisation for stress tolerance. There is also a need to identify any potential alternative crops for severe or chronic stress environments. Any System-wide initiative to quantify crop yield potential under stress should use common genotypes across stresses and regions.

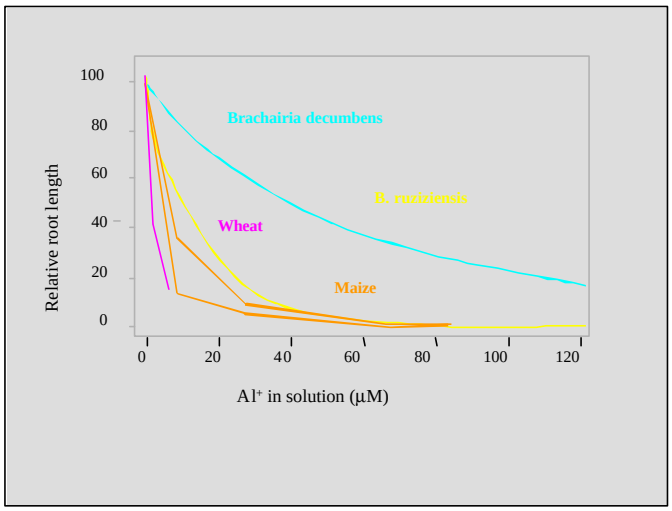


Fig 3 Signalgrass (*Brachairia decumbens*) is far more tolerant of high aluminium concentrations than other *Brachairia* species or 'tolerant' varieties of maize or wheat. Adapted

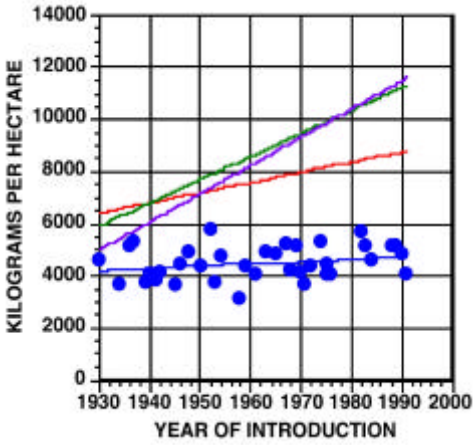
Progress in breeding – slow but real

Some progress has been made in breeding for drought, salt and aluminium tolerance or avoidance. The CGIAR Center breeding programmes have played a major role in these advances, a small selection of which are listed below. In general these have involved incremental, rather than quantum jump, improvements and have been achieved by empirical selection and not, as yet, by MAS.

- Many releases of drought and acid soils tolerant tropical maize varieties released worldwide, e.g. the acid soils tolerant CORPOICA H-108 and H-111 for Colombia, the Pool 25 and population 28 lines for acid soils used the Brazilian programme, ZM421, 521 and 621 recently released in Southern Africa which are both tolerant of low nitrogen and mid-season drought. (CIMMYT)
- Rice releases listed as salt tolerant for Bangladesh, e.g. PSBRc 84, 86 and 88. PSBRc 88 has good eating quality and is planted even in non-saline areas (1999, IRRI)
- Drought tolerant banana variety, FHIA01, bred and released in Honduras, now released in Tanzania and in trial in 50 other countries (INIBAP)
- Heat tolerant potato variety, Unica, released in Peru (1997, CIP)
- Series of durum wheat and barley varieties that have extended the range of these crops in Syria. Chickpea varieties which have facilitated the switch from spring to autumn sown crops (ICARDA)
- Release of drought tolerant Nerica lines, first in Cote d'Ivoire and now particularly in Guinea (1998, WARDA)
- Release of Mulato, a *Brachairia* Al tolerant variety for Mexico and C America (2001, CIAT)

Progress has however been hampered by the perception that, in some situations, stress tolerance and high yields are incompatible. The view that higher yields under stress conditions are incompatible with higher yields under good conditions [17,18,19] invokes the need for independent targeted breeding programmes of specialized varieties. In particular it has been argued that, as drought 'stress intensifies, high yield potential and drought resistance become mutually exclusive'[17]. Counter to this is the conclusion that the improved yield of hybrid maize in the US, where there have been steady improvements since the 1930s, is mainly all the result of selection for response to tolerance to stress [20]and potential yields have not changed over this period, Fig 4.

Fig. 4 Grain yield of maize hybrids regressed onto year of introduction at four planting densities. 10,000 plants ha (i.e. at 1 m spacing) in blue, 30,000 in red, 54.000 in green and 79,000 in blue. Maximum yield potential per plant has not altered over the past 70 years. Increased yielding ability is due to



Yet others [21] believe that decentralized participatory breeding with local partners provides the most viable means of breeding locally adapted lines, and at the same time provides an acceptable compromise accommodating the two opposing views. It may well be that there are good physiological reasons as to why the former view may be true for some crops for some stresses at some levels of intensity.

> Breeding for stress tolerance will proceed more efficiently once it is clear whether, for individual crops and specific stresses, yield potential under stress is controlled by the same genes as yield under optimal conditions. The conclusion will dictate breeding strategy.

Appropriate screens

Selection screens appropriate to the field conditions that new varieties might experience are often problematic. Field trial climatic factors such as drought and temperature are often unpredictable, while uniform stress conditions are difficult to achieve in trials for edaphic stresses. Also different stresses are often found together, for example salinity problems are rarely all due only to common salt, NaCl. In fact stress the field is rarely due to a single factor. For example multiple metal toxicities and deficiencies are often found simultaneously, and these are farmers' field conditions that are very difficult to match in the laboratory or glasshouse.

Of course, in the later stages of a breeding programme, empirical selection under field stress conditions is still probably the available approach for most breeders working in developing countries. Usually breeders will simply select those lines that remain the greenest after a period of stress, even though it is well known that plants retain chlorophyll even after all growth has ceased Fig 5 [22], i.e. that survival is not the same as productivity. The recent developments in thermal imaging and chlorophyll fluorescence imaging [23,24] may provide rapid, economic, non-invasive selection criteria applications over a range of crops and stress programmes.

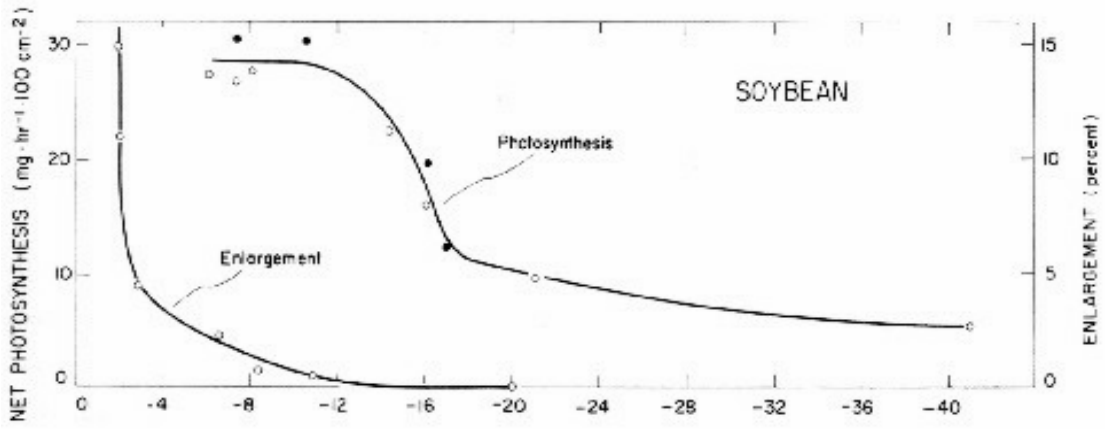


Fig 5 'Green' is not the same as 'growing'. As water potential is lowered (as in increasing drought or salt stress) chlorophyll retention persists after all growth has ceased.

From Boyer, J.S. (1970) Plant Physiol 46, p234 Fig 1 "Rates of leaf enlargement and net photosynthesis in corn, soybean & sunflower plants at various leaf water potentials".

> Good uniform trial sites for stress tolerance selection are not common and where possible should be shared over breeding programmes. The involvement of physiologists with experience of appropriate imaging technologies could benefit a range of CGIAR stress tolerance programmes.

Genomics – the new genetics

Developments over the past decade, arising particularly from the human genome programme, have led to a new phase of plant genetics. 'Plant genomics' is the application of the newly available vast amounts of genomic DNA sequence, using a range of novel high-throughput, parallel and other technologies. In plants a 'whole genome' DNA sequence is available as yet only for arabidopsis, which was 'finished' in 2000. A 'draft' raw almost complete sequence of indica rice has been deposited in the public databases by the Beijing group[9] and a similarly complete sequence of Japonica is available within a private company [8]. The fully annotated public DNA sequence of rice, 88% complete at the moment, will be finished later this year. Undoubtedly more species will follow. Possibly maize will be the next major crop plant to be sequenced, at least for 'gene-rich' regions of the genome. Technologies which are included under the umbrella of 'genomics' are: automatic DNA sequencing, where one machine can read two million base-pair a day; microarrays and DNA chips where tens of thousands of genes can be scanned for activity levels at the same time; automated genotyping machines that can assay tens of thousands of DNA diagnostic points a day. In fact it will soon be possible to monitor whole genomes for genetic markers or gene expression on single chips. Transformation technologies that allow the facile and efficient genetic modification of almost all crop plants can also be considered genomics technologies.

Genomics is still in its infancy. Genomics technologies, beyond the now conventional molecular biology technologies, are being taken up by CGIAR Centers and by NARS. High throughput capillary DNA sequencing machines and micro-arrayers are in place in the Centers, transformation as a research tool is available for most mandated species (see Annex 1).

> The CGIAR Task Force for Genomics met in April 2002 to consider the System-wide accountability and organisation needed for flexible, efficient, sustainable, cost effective genomics for the mandate crops. Some consensus was achieved and more can follow.

Synteny and comparative genomics

A second development, which has also emerged over the last decade, is the discovery that gene content and gene order is much more conserved over even quite distantly related species that was previously envisaged. This is known as 'synteny' [25].

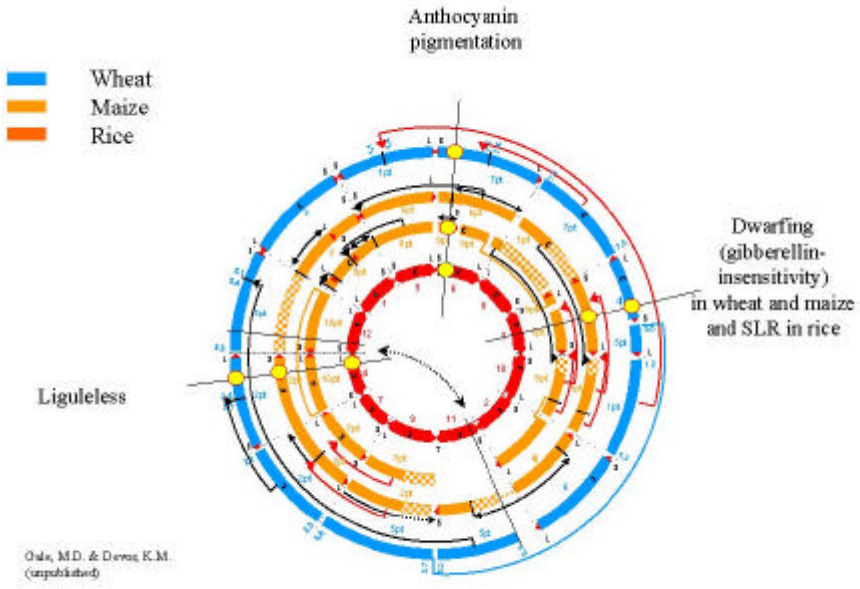


Fig 6 Crop circles. The genomes of the three major cereals aligned syntenously so that homoeologous genes lie on radii. Three homoeoallelic series are shown, including the *Rht* (wheat), *D8* & *D9*

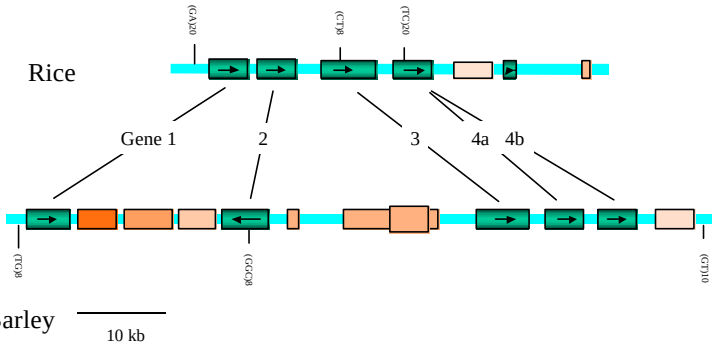


Fig 7 Gene content and gene order is remarkably conserved between rice and barley. As is commonly found, one gene is duplicated in one of the genomes. Also the genes in barley, which has the larger genome, are interspersed with

Synteny over the grasses, where the phenomenon is most clearly documented, has recently been tested in shotgun rice genomic sequence produced by a private company [8]. Almost all the cereal genes, of known and unknown function, and all of the proteins they code for are found to have corresponding genes in the rice sequence. The maps of the genomes of the grasses, which include all the cereal crop species that have evolved over the past 60 million years [26], can be aligned so that the location of a gene known in any one gene can be predicted in all the others [25], Fig 6. A corollary of synteny is, of course, that gene function and role in control of agronomic traits can also be predicted across all the cereals. We should note that the similarity between genomes is restricted to the genes themselves and that intergenic regions differ greatly between even quite closely related species, e.g. as shown in Fig 7, and give rise to the large variation in genome size found in the grasses [27].

The key issue here for the application of genomics tools in the CGIAR crops is that all of the rice resources can be applied directly to the genetic analysis of wheat, maize, barley, pearl millet, finger millet and sorghum. First generation comparative maps have been published for rice and all these genomes.

It turns out that the 240 million years that separate the grasses from the broad leafed plants, the eudicots, has degraded precise map correspondence to the point where the retained synteny does not have predictive utility[8,28,29]. However the arabidopsis sequence and the arabidopsis genomic resources are available and applicable to broad-leafed crops, e.g. tomato [30]. The genome relationships are close within the Crucifereae, which includes arabidopsis and the brassica crops. The Solanaceae and the Crucifereae are more distant from one another at an estimated 150 million years. Nevertheless the arabidopsis gene organization can still be used to aid genetic analysis in tomato [31]. The syntenic relationships between arabidopsis and the majority of the broad-leafed CGIAR crops, particularly the legumes, are not well established (Annex 1).

However other models are emerging which will aid genetic analyses in these crops. The DNA sequence of a legume model, probably *Medicago* (alfalfa), will be available in the foreseeable future. Also work is progressing rapidly with the tomato genome to bring this species up to model status for all Solanaceous crops.

> Breeders and geneticists of cereal crops should become familiar with the relationship of the rice genome organisation and that of their own crop. Breeders of broad-leafed crops where the genome relationships with arabidopsis are not known should have access to the arabidopsis sequence, and should be beginning to establish the syntenic relationships. Novel bioinformatics applications will be are necessary for full application of synteny to crop improvement.

Genomics applications in CGIAR mandate crops in relation to abiotic stress tolerance

In order to employ genomics to address the problems of abiotic stress in mandate crops and to be able to exploit synteny, rather than simply rely on solutions formulated in the models, a basic genomics infrastructure in the crop itself is required. The bare minimum is probably a molecular framework map of the chromosomes, a large DNA insert library, and a facile (and reasonably efficient) transformation system capable of delivering relatively large numbers of engineered plants. The map will have markers every 2 or 3 cM and will have a number of anchor loci, RFLPs or ESTs marked with SSRs or SNPs, that will allow comparisons with the appropriate models. The library will probably be a better than 2-times coverage BAC library with insert sizes in excess of 100 kb.

Additional resources that will be of value include a collection of ESTs (transcribed gene sequences), a comparative map and some 'knockout populations. The ESTs will often be comparative collections from stressed and non-stressed plant tissues. The comparative maps will align syntenous chromosome regions of the crop with the model. The knockouts will probably be mutation or deletion libraries in which genes have been disabled at random, although T-DNA tagged or transposon-tagged population, as are available or under development in arabidopsis and rice, are also possible when a good transformation system is available.

Extensive public sector genomics resources are available for maize, wheat and rice. Genomics resources for other CGIAR crops, such as pearl millet, sorghum and *Musa*, are being created in collaborations with ARIs. Other crops such as bean, cassava and *Brachairia* are being worked up within the CGIAR System and yet others, such as forage legumes, beans and chickpeas, have yet to be started (see Annex 1).

> At the very least base genetic maps should be available for all CGIAR crops (a microsatellite-based map would today be the work of a 3-year post-graduate student). This will open up all species to MAS breeding. Further resources may easily be added at a later date. Links with ARIs or direct outsourcing should be explored for EST and BAC library production.

Gene cloning

There are many ways to clone genes, however if all that is available is a map location of a stress tolerance gene and there is no indication of its precise function, then the process will probably be either to identify possible candidate genes by their map position or to find genes whose expression is associated with the trait. Certainly in order to find out unequivocally what any gene actually does it will generally be necessary to clone it first.

Map-based cloning

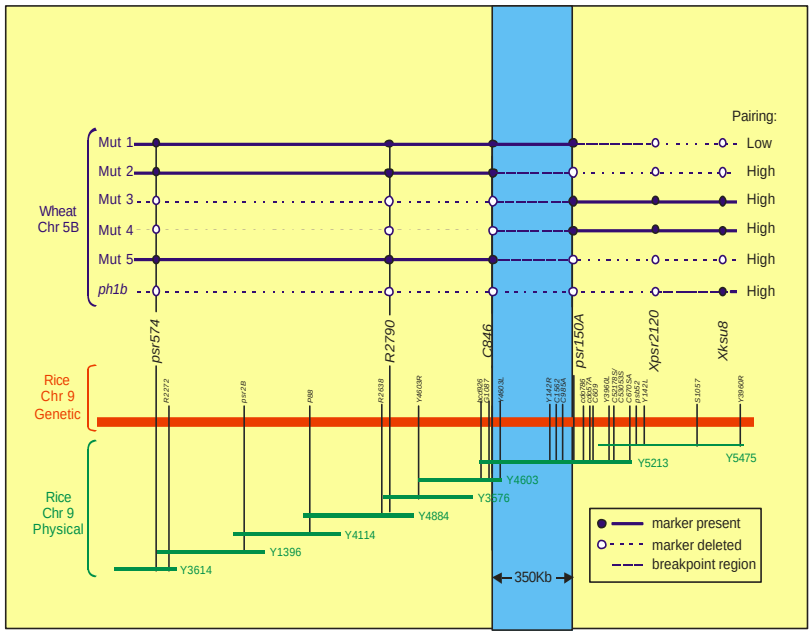


Fig 8 Deletion tiling. In an experiment to isolate a wheat gene, *Ph1*, which controls chromosome pairing, the critical wheat chromosome was aligned with the syntenous chromosome in rice. Then a series of 'knock-out' deletions in wheat, identified by their *Ph1* phenotype, were produced. The individual wheat deletions are Mb long. However the minimum overlap region of these deletions (shown in blue) defines a mere 350 kb region of rice genome in which to search for candidate genes. Adapted from Roberts et al (1999) Genetics 153:1909

When the alignment of the crop and model maps is available candidate genes mapping in the region of the QTL in the crop can be identified directly from the

model DNA sequence. With around 30 genes per map unit, as in rice, it will usually be necessary refine the map location of a QTL, which has been reduced to an identifiable major gene by this time (a process sometimes referred to as 'Mendelisation'), in large segregating populations. BAC contigs, overlapping linear series of large insert clones, can also be made in the crop itself using DNA landmarks gleaned from both the crop molecular map and the model sequence.

A novel method of map-based cloning, known as 'deletion tiling', involving the generation of a number of deletions that include the target gene in the crop, and using the minimum overlap to identify candidates in the model, is being pioneered in wheat, Fig 8 [32]. This method has the advantage that variation is not required for either the target gene or the flanking DNA regions, and it could find many applications in CGIAR crops.

Microarrays

Candidate genes will also emerge from microarray analyses. Genes that are induced by stress are ideal for comparative microarray analysis. A typical experiment will be to challenge an array of ESTs with RNA extracted from stressed and unstressed tissues. A comparison of the two will identify genes that are up-regulated in the stressed tissues and those which are down-regulated or switched off, Figs 9 and 10. Whether these represent genetic cause or effect is another challenge. Ideally one would like these experiments to scan entire genomes because, until all genes are available, any microarray experiment will always be incomplete. This will be possible in the near future for the 25,000 arabidopsis genes and the 50,000 rice genes, but not for other crops for some time. Mini-array's can however be built from collections of ESTs assembled from random cDNA libraries, or from more targeted collections made from cDNAs collected from stressed tissues. Even more targeted will be the special 'stress arrays' made up of all the expressed genes for which there is any evidence of implication. Stress arrays are being contemplated in several CGIAR Centers. Other technologies such as cDNA-AFLP and differential display can also identify critical gene sequences.

A major NSF grant [33] has recently been completed which has investigated the use of arrays to investigate salt tolerance. This project has made a commendable start to cataloguing stress inducible genes in halotolerant and salt-sensitive plants. The results are generally relatively complex For example, in rice 10% of the genes were significantly up- or down-regulated after 1 h of salt stress [34]. An added complication is that almost half of the genes available as ESTs or as hypothetical genes in genomic DNA sequence have, as yet, completely unknown functions.

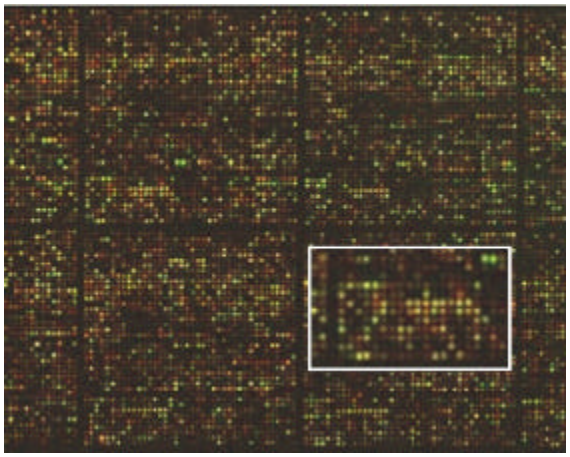


Fig 9 Micro-arrays can carry 20,000 genes on a 2 cm^2 plate. When arrays are probed with RNAs from, say, stressed and unstressed plants computer enhanced imaging identifies genes that are under-expressed (in red) and over-expressed (in green).

Plainly microarray analysis has a role to play and the CGIAR groups should be gaining experience of the technology. However it is equally clear that microarrays alone will provide complex correlative data which will require considerable further refinement using, for example, knockout phenotypes and QTL location-related map data in order to tease out the causal genetic elements. Candidates from the arrays that coincide with the candidates from map-based approach will be of significant interest.

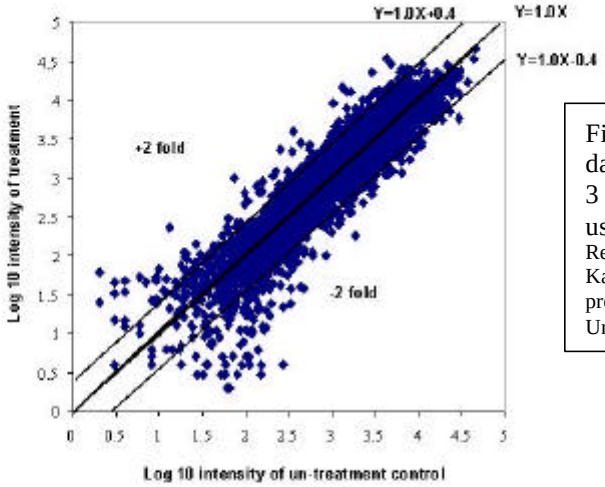


Fig 10. Microarray data. Rice response to 3 h drought stress, using 6,400 ESTs. Research by Shinji Kawasaki. Figure kindly provided by Hans Bohnert, University of Illinois.

Comparisons of the DNA sequence or the hypothetical protein product sequence with other isolated genes of known function can provide a lot of information. However while some half of the genes revealed by whole plant genome sequencing remain of unknown function, it will often be necessary to attempt to elucidate function by various reverse and forward genetics methods including transformation and knockout analysis, in both the crop and the model. The definitive experiment will usually involve the production of transgenics with an expected phenotype.

Knockout populations

Various T-DNA or transposon tagged populations are available in rice and arabidopsis. These reverse genetics 'gene machines' allow the identification of lines in which any gene of interest is disabled. These lines can then be investigated to identify a phenotype that may give clues as to the genes function. A recent development, TILLING (from 'targeted induced lesions in genomes') [35,36] allows production of targeted knockouts and also the creation of allelic series in any gene. TILLING populations are available for arabidopsis and are under investigation for rice.

Chemical or irradiation mutant populations in the crop itself will allow a forward genetics approach. Stress tolerant lines can be identified by the simple expedient of subjecting populations to drought, high salt, cold temperatures, submergence etc. and selecting vigorous survivors. The challenge then is to link the

phenotype with a deleted gene for which the sequences of candidates will be a good starting point.

> With the notable exception of rice, CGIAR germplasm curators have not entered the field of knock-out populations in mandate crops. CGIAR Centers and NARS have significant comparative advantage in having the facilities to grow and maintain large populations, and they have the expertise in the crop to recognize and screen for key knockout phenotypes. These populations will be central to functional genomics efforts and, especially for the minor CGIAR crops, their availability should encourage collaborations with ARI researchers working in model species. The opportunity costs of not taking an international lead of this sort should at least be evaluated for all of the mandate crops.

Transformation in the crop and the model

Genetic transformation is now possible for most crop species. However 'possible' is not the same as 'efficient'. CGIAR Centers need to be able to produce at least tens, and ideally hundreds, of low copy insert transgenics for any construct (the need for many lines is demonstrated by the range of phenotypes produced in any single transformation experiment, see Fig 14). Good systems exist for many broad-leafed crops and for most cereals. Legumes are probably the most recalcitrant group of crop plants. The status of CGIAR Center transformation capability is shown in Annex 1. Transformation is often seen only as means of making transgenic crops. Indeed, the ideological debate surrounding transgenics notwithstanding, it is inconceivable that we will penetrate far into the 21st Century and its looming food shortages without needing to use all the technology that we have available. However for the time being, transformation has another use as the ultimate test of function of any candidate gene, either in the model or the crop.

Initial attempts will usually employ constructs of the beneficial allele of the gene linked to a constitutive promoter, such as CMV35S, in over-expression experiments. Early transgenic trials will also usually involve antisense constructs that will provide information by negating the effects of the gene. Later trials in the crop itself will probably employ specific alleles of the gene in constructs with promoters that target the effects to specific tissues, such as roots or developing seeds, at particular developmental stages. Transgenics in the crop itself will likely be in an already otherwise adapted genetic background, and these may serve as breeders' lines for eventual introduction into the main stream breeding programmes.

Leads from model species

Research into the molecular basis of abiotic stress tolerance is being carried out mainly in model species, particularly arabidopsis. Although this area of our science is still in its infancy there are some 200 references and claims in the reputable scientific press. Genetic transformation experiments to improve stress tolerance are beginning to yield some promising results.

A particularly encouraging approach is the use of transcription factors, regulatory elements that control batches of genes, including those which are induced by stress. One such is *CBF1* in arabidopsis, which is the likely regulator of the cold acclimation response. Over-expression of *CBF1* enhances the levels of a swathe of cold-regulated genes to mimic the effect of cold acclimation that provides subsequent resistance to freezing, and provides protection against cold temperature damage, Fig 11 [37]. Transcription factors act as 'master switches' and provide one means of rationalizing and exploiting the information obtained from gene expression microarray analyses.

DREB1A is another transcription factor that regulates expression of a further range of stress tolerance genes. Over-expression of *DREB1A*, again in arabidopsis, activates expression of a range of genes and results in improved drought, salt and freezing tolerance [38].

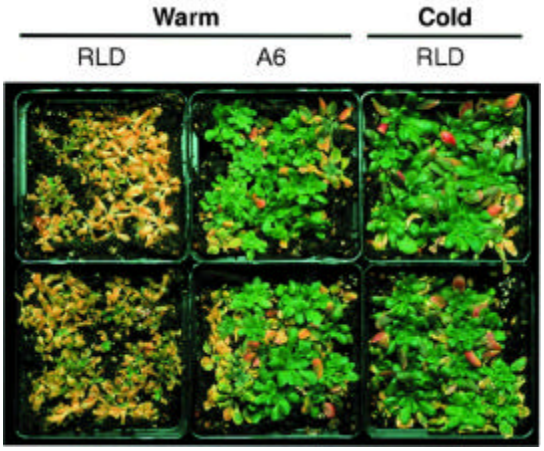


Fig 11 Effect of *CBF1* over-expression in arabidopsis, *Left*: Non- acclimated controls after freezing for 5 days; *middle*: Non-acclimated transgenics after freezing, *right*: Acclimated controls after freezing. Reprinted with permission from Science 280, p 105, fig 3 "Freezing survival of RLD and A6 Arabidopsis plants", Jaglo-Ottosen et al. Copyright 1998 American Association for the Advancement of Science

Interestingly it was noted that, when *DREB1A* was driven by CaMV35S, a strong constitutive promoter, normal growth of the plants in an unstressed environment was severely retarded. However the simple expedient of driving *DREB1A* with a stress inducible promoter reduced adverse side effects and further improved tolerance. Negative pleiotropic effects on fruit yield were also seen in tomato with CaMV35S driven yeast *HAL1* gene, which enhances K^+/Na^+ selectivity and maintenance of water status [39].

Specific 'ideotype' approaches have also been tried. For example, it has been argued that plants should be able to exploit ions to achieve osmotic adjustment and internally distribute these ions to keep sodium away from the sites of metabolism. To achieve just this a vacuolar Na^+/H^+ antiport, *AtNHX1*, was over-expressed to provide protection up to about half seawater salt levels, Fig 12 [40]. Similar effects have been demonstrated with *AtNHX1* over-expression in oil seed rape, *Brassica napus* [41].

Fig 12 Over-expression of the antiport gene, *AtNHX1*, provides tolerance to salt in arabidopsis at levels up to 200 mM. Reprinted with permission from Science 285, p1258, fig 3 "Salt treatment of wild-type plants and plants overexpressing at At NHX1", Apse, M.D. et al. Copyright 1999 American Association for the Advancement of Science

There are many opportunities using the transgenic approach, including, eventually, to produce lines that can be entered into mainstream breeding programmes. Novel genes can be expressed with increasing precision, as more tissue and developmental time specific promoters become available. Endogenous genes can be over-expressed, or negated by the use of antisense constructs.

Interestingly, synteny can also be exploited to good effect. Once the molecular basis of beneficial alleles in any species, has been discovered, including in models like arabidopsis, it is possible to engineer the equivalent homoeologous genes in the target crop with the same alterations in DNA sequence. An excellent example of this approach is the recent targeted engineering of rice to produce a GA-insensitive dwarf phenotype. In 1997 the GAI gene, which produced a gibberellin insensitive dwarf

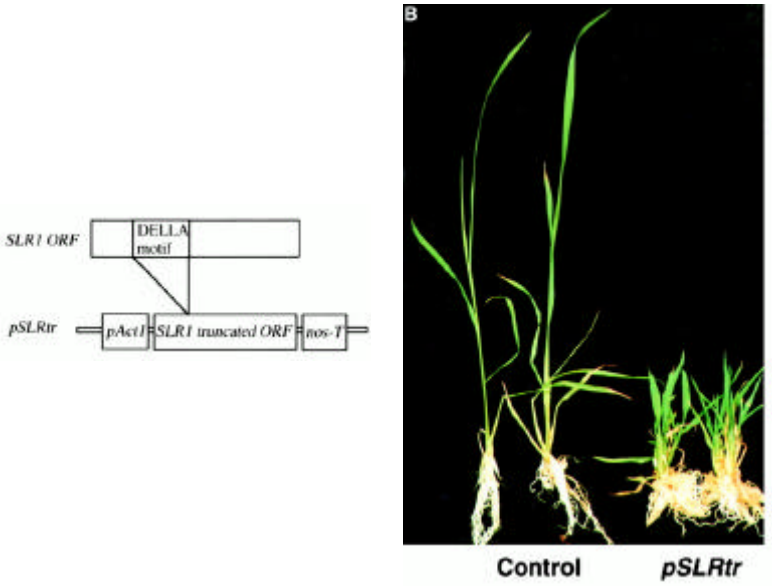


Fig 13 *SLR*, at the rice homoeologue of arabidopsis *GAI* and the wheat 'Green Revolution' *Rht* genes can be engineered to produce the equivalent dwarf phenotype for rice.
From Ikeda, A. Ueguschi-Tanaka, M. Sonoda, H. et al (2001), The Plant Cell 13, p 1006 fig 8B "Truncation of the DELLA motif in SLR 1 leads to a dwarf phenotype".

phenotype was isolated from arabidopsis[42]. Soon it was it was possible to demonstrate that rice homoeologues (found in rice ESTs) of the arabidopsis gene mapped to locations in cereal genomes that coincided with the location of the 'Green Revolution' wheat semi-dwarfing genes. Moreover the allelic difference between tall and dwarf phenotypes of both rice and wheat were based on the same 51 base-pair (17 amino acid) deletion in homoeologous genes[43]. Just last year, a Japanese group[44] added the last step when they were able to demonstrate that they could engineer the equivalent rice gene (*SLR*), for which no dwarf mutant had ever been found, with the same 51 bp deletion and produce GA-insensitive dwarf transgenic plants (Fig 13), and thereby avail rice of a completely new and potentially very valuable form of short straw. The same paradigm can, and undoubtedly will, be used to transfer alleles between quite distantly related plants and will no doubt be of value for transferring stress tolerance genes between crops and between wild species and crops.

Finally we should note that the process of transformation is not yet an exact science, as demonstrated by the range of reduced height phenotypes produced by transforming rice with *pSLRtr* [44] (Fig 14). An efficient transformation system will produce a range of 'alleles' from which to choose the 'ideal' phenotype.

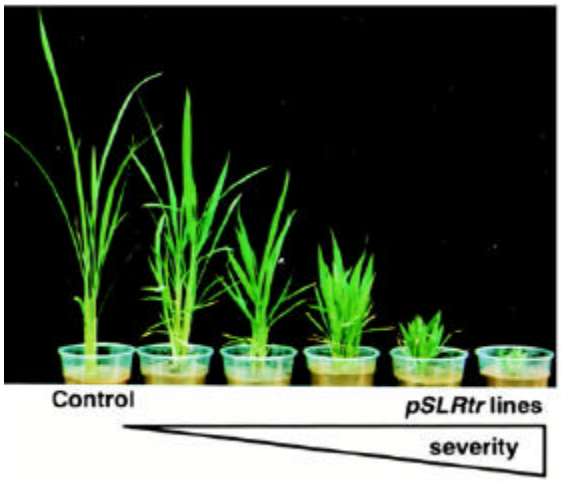


Fig 14. The same *pSLRtr* construct produces a range of transgenic 'alleles'. From Ikeda *et al* (2001) Plant Cell 13:999

There appears to a tremendous potential in these results on stress genetics, either in the direct application of model plant gene constructs in crops or in the modification of endogenous crop genes to emulate the effective model plant alleles. The arabidopsis *DREB* genes have already been transferred to wheat with most encouraging effects on salt tolerance[45]. Most CGIAR Centers have effective transformation systems for their own mandate crops and could enter into collaborations to obtain the necessary genes, at least for research purposes.

Nevertheless we should not forget Abraham Blum's warning that '...any claim for a genetic modification of stress resistance that is presumed to impact crop performance in agriculture will remain on paper unless proven …. under field conditions'[45]

Germplasm collections – allele mining and association genetics

The collections held in trust by the CGIAR Centers and by many NARS have major roles to play in both candidate gene discovery and, once genes have been identified as being important in the control of a trait such as stress resistance, identifying the range of alleles available at that locus. It is very clear that these collections will increase in importance. Everything that can be done should be done to provide added value over the next few years.

'Allele mining' will involve PCR-extraction and sequencing of the different versions of genes found in varieties, land races and wild relatives. Variation in gene sequence may then be correlated with the stress tolerance performance of the accession, and may well identify the best alleles for future transgenic experiments.

'***Association genetics'*** is a collection-related development that the CGIAR Centers are particularly well placed to exploit. This new area of science derives from human genetics where analysis of large segregating populations is not possible. Genes associated with any trait are identified by correlation of phenotype with specific

alleles at linked markers. In plants this involves scanning collection accessions for variation at marker loci dispersed over the genome (genotyping) and then correlating, for example, performance under stress of the genotypes with allele dis-equilibrium around the genome. This a young science in plant biology, however the potential is great for discovering novel genes of adaptive significance and for providing added value to the collections. It will not go unnoticed that, once the collection has been 'genotyped', the same data is applicable to any trait of interest.

> CGIAR Centers are advantageously positioned to develop plant association genetics. The biodiversity discussion has increased public awareness of the value of *ex situ* collections and any genotyping and further characterization will increase their value still further. Again the technology and the analyses will be generic so there is much to be gained by close System-wide collaboration

Conclusions

Abiotic stress is a major constraint to food production and one that will grow in significance as we approach the increasing world food shortages in the developing world that will characterize the first half of the 21st Century. Aid and technology may be available from the North but the problem is one for the developing world alone. New crop varieties that will produce more in increasingly marginal agricultural environments will be desperately needed. These varieties will be bred only by the CGIAR System and their national agricultural programme partners.

Considerable collaborative work, usually with NARS and often with ARIs, is already underway for most mandate crops from most Centers. Levels of expertise and motivation are high. However the various projects are crop and region specific and are being carried out in relative isolation.

The new science of plant molecular biology is beginning to impact all of our work, including stress tolerance research and breeding. Comparative genomics in particular promises new opportunities and is developing fast. Researchers in ARIs are already making discoveries that will impact stress tolerance breeding, and they are highly motivated to work with developing world problems. CGIAR scientists have been quick to appreciate this and are collaborating with key academics and are beginning to import and install the technology. However the notion that any single Center can keep at the cutting edge of this fast moving and expensive field must be unsustainable. The science is generic and the need for centralization, rationalization and outsourcing will become obvious to everybody soon. The centralization, at least to virtual centres, could extend to personnel with key skills as well as technologies.

The sooner we start the better prepared we will be for the future. A pan-crop, pan-Center global collaboration involving NARS, key ARIs and even industry, to approach the problem of abiotic stress tolerance, building on what has been achieved already, could be the vehicle around which to begin to build this new way of doing science. The notes below will provide a basis upon which to open the discussion.

Options for the way forward

In the CGIAR there is already a wide understanding of the importance of stress tolerance. There is tremendous motivation, and considerable ongoing work, to breed new varieties of CGIAR crops with improved tolerance to stresses. Most Centers have incorporated molecular biology into their science and their breeding. Genomics technologies are beginning to be absorbed by the leading Centers. Links are already being made with the ARI scientists working in the area of abiotic stress tolerance. Technology transfer is continuing through the established CGIAR Center-NARS networks.

Even since the first draft of this discussion document in April 2002, progress has been made. The 'fast-tracked' Global Challenge project 'Unlocking genetic diversity in crops for the resource poor', already submitted by CIMMYT, IRRI and IPGRI, has incorporated the potential of molecular genetics and genomics to mine the CGIAR germplasm resources for novel genes and alleles that can be employed to improve the characteristics of varieties in developing countries, particularly for abiotic stress resistance. In fact an approach to drought tolerance is included as an example for 'proof of concept'. So with regard to abiotic stress comments will be restricted to a list of goals for a successful co-ordinated approach and a few suggestions for further work that have not been incorporated into the GCP. More attention will be devoted to ways forward to build a pan-System corporate knowledge of genomics technologies and to provide a genomics infrastructure that will make the CGIAR System the preferred partner for national programmes and provide the System itself with state-of-the–art technology for the foreseeable future.

Abiotic stress research in the CGIAR Centers. The arguments developed above indicate that there is a need for a highly co-ordinated pan-crop approach that seeks out and exploits the comparative advantages of all the partners. The approach will also exploit the generic aspects the new genetics and comparative genomics.

The overriding goal must be to produce varieties that will extend the range of arable agriculture and yield more under stressed conditions to provide improved food security for the poor of the world.

Sub-goals will include:

- Implementation of an initiative which will underpin stress breeding programmes by providing good science and the best tools to address different problems, without duplication, including:
    - novel genes, and improved versions of genes, to address abiotic stress tolerance
    - improved breeding tools for more efficient incorporation of these genes in new varieties, e.g. better selection screens, better molecular markers, more efficient transformation protocols
    - information on the most appropriate breeding strategies, e.g. whether, for specific crops and specific stresses, breeding can be integral to the core programme, should comprise a separate specialized programme or would be better outsourced to participatory programmes

- improved knowledge of the physiology and biochemistry underlying stress tolerance.

- Provision of a framework to ensure a continual flow of information between keys ARIs, Centers and NARS. Also the provisions of a forum where ARI scientists can be exposed to the problems encountered in developing countries, and at the same time allow Centers and NARS access to ARI stress science and generic technology.

- Exploitation of the generic experience in molecular genetics and genomics technology, and exploitation of the new opportunities arising from the discovery of synteny between crop genomes, and between crops and models.

- Bringing key skills together to link with breeders to address the problems, e.g. molecular physiology, bioinformatics, genomics technology, IP management etc., particularly where all these skills are not present in a single Center

A successful initiative will exploit the comparative advantages of all potential partners:

- NARS – national breeding programmes will have access to the most relevant stress trial sites, increasingly NARS will have molecular biology and genomics expertise, together with skills which are becoming uncommon in the CGIAR, such as physiology and biochemistry. NARS will know local market drivers and will be able to interact will local relevant industry, such as plant breeding and seed companies.

- ARIs – Advanced Research organizations will provide access to state-of-the–art genomics, and, notably, a few genomics laboratories specializing in abiotic stress. ARI's will provide access to arabidopsis genomics, including the first whole genome arrays, bioinformatics, and biochemical pathway research.

- CGIAR Centers have a specialized knowledge of the mandate crops, including genetic transformation, availability of field and glasshouse space for trials, and a growing bioinformatics, molecular genetics and genomics capacity. CGIAR Centers hold the key germplasm collections. The Centers have special relationships with NARS and networks in place to transfer technologies

- Industry – The multi-national agbiotech industry does undertake some fundamental and strategic and controls some results relevant to Centers' needs. The first whole genome rice arrays are likely to be available from industry. Smaller specialized, often local, companies can provide market-tested genomics service providers, e.g. BAC libraries, DNA sequencing, which will provide benchmarks for Centers planning their in-house/outsourcing research strategy.

The goals and objectives above are embodied in the 'Unlocking genetic diversity in crops for the resource poor' Global Challenge programme. One outstanding recommendation concerning crop replacement should be considered. Although crop improvement to tolerate local will probably be preferred it will be very valuable for agronomists to have available lists of alternative crops that are inherently

more tolerant of particular sub-optimal soil types or particular adverse climatic conditions. The compilation of such information for global application would be very valuable indeed.

Genomics and genomics resources in the CGIAR. It is very clear that genomics will play an increasingly important role in CGIAR science and crop improvement. It is equally clear that genomics platform technologies are the most expensive, and probably the most rapidly advancing, that the System has ever had to accommodate. Therefore an early single pan-System policy for the acquisition and deployment of these technologies is imperative.

The goal should be to provide Centers and NARS partner's access to the appropriate genomics resources for all the mandated crops and sustainable access to state-of-the-art platform technologies and plant genomics capacity.

An initiative to achieve this would have a number of sub-goals:

- Should be cost-effective and achieve economies of scale while still being flexible and responsive to new developments.
- Providing the CGIAR Centers and NARS access to the rapidly changing state-of-the-art genomics technology.
- Allowing smaller Centers working with wider portfolios of marginal crops to learn from the experiences of the Centers concentrating on the major staples.
- Providing a framework to ensure a continual flow of information between keys ARIs, Centers, NARS and commercial technology suppliers.
- Providing Centers and NARS access to model plant, e.g. rice, *Arabidopsis*, *Medicago*, tomato etc., genomics resources.
- Developing ways of outsourcing *between* Centers
- Providing access to common negotiated sources for standard within-crop genomics services.
- Achieve a minimum basic 'in house' genomics infrastructure at the Centers for each crop, e.g. genetic maps, comparative maps with models, BAC libraries, EST collections, efficient transformation methods, genotyped QTL mapping populations (possibly also 'knock-out' libraries), to be shared across the System and with NARS and as vehicles for collaborations with ARIs.

The policy should enable the build-up of pan-System corporate knowledge and capacity of technologies, including:

- ESTs, cDNAs and BAC library production
- marker development – SNPs and, possibly still, SSRs
- high throughput (HTP) genotyping – both for SSRs and SNPs
- association genetics as applied to in-house germplasm collections
- map and comparative map construction and application in mandated crops
- fully genotyped segregating populations for QTL applications
- comparative genomics and bioinformatics, particularly between mandated crops and models
- insertion/mutation populations, TILLING

- handling and storing genomics resources, using laboratory information management systems
- microarrays – both built in-house and 'bought in' Affymetrix-type arrays
- proteomics
- high throughput DNA sequencing
- transformation protocols

All of the above technologies are, or will soon, be required by all Centers. The issue is whether any particular technology is best centralized within Centers, centralized somewhere within the System or outsourced altogether. Centralization and outsourcing between Centers will certainly become necessary as technology, and associated costs, evolve to soon become beyond the scope of any one Center. Costs are, of course, not the only determining factor. Convenience, service level, relationships between customers (particularly between Centers and NARS) and training considerations will all play their part.

Precisely these issues were considered two years ago and reported in the TAC 'Systemwide review of plant breeding methodologies in the CGIAR' [46]. The review emphasized that outsourcing and, especially, outsourcing *between* Centers should become common for some technologies. The report also noted that centralization should be considered for technologies that had 'broad utility for all Centers', were 'so expensive that individual Centers cannot afford it', and where' information transfer was synergistic'. In the intervening two years at least two of the CGIAR's genomics technologies have moved into this group.

Below most of the technologies are briefly considered from this point of view.

ESTs, cDNAs and BAC library production should probably all be contracted out, and there are excellent suppliers out there. These are resources that will be revisited over and over, for which quality is paramount. Quality large insert BAC libraries in particular are very reliant on experience and the availability of the appropriate colony picking robots, which will not be present in any Center.

Molecular marker development. This is still a critical activity for many crops (see Annex 1). SSRs are generally identified in various enriched libraries or directly from EST sequences. Libraries will probably be made in collaboration with expert ARI labs and the sequencing contracted out directly. SNP detection in the non-staples (where e-detection is not possible) will again probably be by sequencing PCR copies of cDNA sequences from different varieties. A job for outsourcing.

Of course the marker only acquire real value once they have been located in a map framework. This mapping will probably be carried out within Centers (see **genotyping** below)

Genotyping – High throughput genotyping should by now be part of most CGIAR breeding programmes. Using SSRs, although there is trend among industrial groups for global centralization, I would still recommend development of relatively HTP systems within Centers. These should extend to liquid handling robots for mass PCR and automatic reading of fluorescent labeled products. Proximity to the users – breeders, germplasm curators and geneticists – and the availability of a local system

for training purposes argue for in-Center systems. These facilities could also be a focus for specific crop NARS breeders' use and training.

All indications are that MAS and germplasm collection characterization will soon move to HTP SNP genotyping. At present the favoured SNP format has not yet emerged, however when it does it will probably be beyond the financial reach of individual Centers. There are other factors mitigating for centralization of such a facility. These include large economies of scale and value in having collections of primers at a single site. Also Centers should be incentivised to use a centralized site which represents even a small part of their budget.

A watching brief should be kept on developments, particularly at international breeding companies with interests in multiple crops.

Map construction and development of genotyped QTL mapping populations will be carried out within Centers, although the development of crop-model comparative maps will likely be carried out in collaboration with ARIs with expertise in the models.

Mutation and deletion populations, other forms of 'knock-out' lines, possibly 'targeted induced lesions in genomes' (TILLING) populations have not, other than in rice at IRRI, been considered at the Centers. Such genetic stocks play a key role in functional genetics, i.e. assigning function to anonymous gene sequences. The Centers, with their specialized knowledge of the crops and, generally, the space and the manpower to grow large populations under good agronomic conditions, have a comparative advantage in the production of such stocks for the mandated crops. The leveraging power of such resources in the promotion of interactions with ARIs and even companies is obvious. The Centers should carefully consider the opportunity costs of not producing such resources.

Microarrays are of two main types. The first are the high quality, high-density GeneChips produced commercially by a commercial company, Affymetrix, using short 16-32-mer gene-specific oligonucleotides built up on the chip. These include the recently produced 24,000 gene (400,000 spot) whole arabidopsis genome arrays (and, in the near future, barley and rice whole genome arrays, and, in the foreseeable future, wheat, maize etc). The only option at the moment is to buy such chips in (about $700 each or $4,800 including sample processing for a minimal experiment) and process them on an Affymetrix Genechip system costing around $150,000. The second type usually use 'spotted' cDNAs or larger 50-70-mer gene specific oligos and can be made within academic labs. Modern arrayers can work up to 20,000 spots, and cost around $50-100,000. This sort of facility will usually be associated with significant liquid handling capacity to enable the large numbers of PCR reactions necessary. Also, significant -80°C freezer space will be needed to accommodate the growing amplified cDNA resource. Finally, in a perfect world, one will validate all amplification products by resequencing, so a HTP sequencer may also be required.

It is generally acknowledged that the value of special arrays, such as the rice stress arrays being developed at IRRI, is very dependent on their quality, and this means dedicated expert technical staff associated with a facility. Chip production could be outsourced or centralized within the System, with obvious advantages and

disadvantages, but clearly the development of multiple facilities around the Centers is not the best option. Among the advantages the development of quality controlled libraries of cDNAs all in the public sector or for which IP issues are known to have been centrally negotiated. Since it will, for quality control purposes, probably also be necessary to run the hybridizations at the same site, gene expression databases will be developed which are available to all users. A System-wide facility will be useful for training of other Center and NARS staff. Return on capital outlay is also a factor with an in-house facility. The thinking is that a top-flight arrayer purchased today would remain 'current' for three to four years. Bioinformatics support, both for the direct analysis of results and comparative analyses of the rapidly growing array result databases, is vital and must be factored in to an in-System facility.

Proteomics. Protein analysis, such as performed 'time-of-flight' mass spectrometers is currently outsourced. The cost of the equipment and the rapidly changing state of the art will probably ensure that outsourcing is favoured for the time being.

DNA sequencing. For relatively large-scale sequencing, e.g. several BACs, ESTs in the 1,000s, outsourcing will be the preferred route. This is a very competitive commercial market. Local sequencing capacity within Centers may still be justified for small jobs. Nevertheless, other issues, like the present Indian policy of not allowing DNA to leave the country, may also convince Centers to retain some sequencing capacity.

Laboratory management systems. It will soon become clear that laboratory information management systems (LIMS) are vital for tracking samples and maintain quality control in the laboratory. At present there are none in use around the System (although CIAT are exploring options). The eventual benefits will be large if all Centers were to use the same, or compatible, systems.

Genetic transformation is most definitely required in-house and for all crops, although development of the technology may be best carried out in collaboration with ARIs.

The way forward. For cost effective pan-System provision of state-of-the-art genomics infrastructure and technologies iSC might consider the appointment of an independent **'CGIAR Genomics Facilitator'**. The initial JD might include:

- a constantly updated trans-national review of outsourced providers and costs for DNA sequencing, DNA library production, proteomics analyses, micro-array facilities and high-throughput genotyping, i.e. constant market testing
- a constant review of outsourcing possibilities between Centers
- act as a clearing house for CGIAR and NARS genomics related queries
- a review of LIMS available, with a view towards harmonization across the System.
- undertake a special study of the advantages and costs associated with CGIAR centralized micro-array and HTP SNP genotyping services.

and, if such facilities move ahead

- the collection of international genomics resources under appropriate MTAs for use with all CGIAR Centers and their stakeholders
- interaction with local managers to establish service level agreements and appropriate financial structures
- commission the development of a web-based tracking system whereby CGIAR and NARS customers can follow the progress of their samples in real time and automatically receive results. This is a key component of any effective and competitive service.

I believe that any System-wide genomics service should also be overseen by an **International Stakeholder Steering Group**. This group will include technology experts (probably managers of service laboratories in developed countries), CGIAR representatives (probably at the DG or DDG level) and NARS representatives. The role of the group will be ensure that the service(s) are state-of-the-art, competitive and appropriate for the major CGIAR and NARS customers.

Line management and financial structures will of course need considerable discussion. Operational models like that of Central Advisory Service (CAS) for intellectual property matters at ISNAR should be explored. Also it is possible that the independent facilitator could be closely aligned with, or even be part of, the ISNAR Biotechnology Service (IBS). Plainly a Genomics Facilitator will regularly report and interact on activities through the existing CGIAR Genomics Task Force and the post could report to the System through the chair of that group.

Further activities. Yet another role of a Genomics Facilitator might also assemble and work with multidisciplinary teams, again in actual or virtual centres, across and over crops to address specific issues. The CGIAR Genomics Task-force is an excellent vehicle through which such groupings could meet:

- Crop type groups. Cereals, legumes and roots and tuber groups have already been initiated. Certainly the development of stress arrays and anchor markers over related genomes will be crop group activities. These groups will have also specific comparative bioinformatics needs

- Bioinformatics. CGIAR over crops bioinformaticists are already linked through System-wide projects to ARIs in the US and the EU and have skills appropriate to all crops.

International meetings, such as Plant and Animal Genome that is held at San Diego every January, provide excellent opportunities for CGIAR scientists to interact with international academics in:

- Crop groups. These already exist and many individual crops are already the subject of international meetings and annual meetings at PAG. A global *Musa* genomics consortium has also recently been formed [47]

Annual meetings organized by CAS at ISNAR or elsewhere for:

- Intellectual property managers. Already in place with CAS at the hub, common systems and corporate knowledge, particularly in dealings with industry, are vital. Similarly common IP arrangements should be anticipated across the System for collaborative grants with ARIs, particularly IP for humanitarian use. The System-wide IP group should also be the preferred partner for NARS.

So finally, rapidly moving research cusps, increasingly expensive technologies, more obvious links between traits and over crops, and increasing technological capacity in NARS are all indicative of more rationalization, more centralization, more outsourcing, and more virtual groupings over institutions. The time when we adopt new ways of working cannot be put off much longer.

An appropriate first step forward would be to convene a meeting of the key CGIAR stakeholders to formulate ways in which the new science can be brought to bear in the most efficient manner to deliver the new crops that developing country agricultures need. Such a workshop would be organized by the CGIAR Task Force on Genomics.

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ANNEX 1

Original

Center	Crop	*Genetic maps*	*Comparative maps*	*Mapped SSRs*	*QTL mapping*	*BACs*	*ESTs*	*Micro-arrays*	*DArT*	*Transformation*	*Insertion/mutation libraries*	*Alien introgression from*
IPGRI	Musa	***	.							**		
(INIBAP)	*M. acuminata*		.			*** & **	***					
	M. balbisiana		.			**	0					
CIAT	Cassava	****	.	***	***	***	[851] (starch)	**	*	***	.	
	Bean	****	.	***	P def, drought	(***)	***leaf & root	** P def	**	.		
	Brachiaria	***	.	***	* Al toxicity	.	**root	*Al	*	**	.	
	Rice	[4000]	Cereals	[400 + 000s ex sequence]	***	[Several libraries]	[105,000]			****	Ac/Ds (USDA)	****O. rufipogon* *O. glaberrima* *O. barthii*
WARDA	Rice	.	Cereals	see above		see above	see above					***
IRRI	Rice	.	Cereals	see above	drought salinity Zn, Fe, P def Fe toxicity	see above	[see above] Panicle (root, shoot)	drought salinity	**	****	Mutation/(Activation mutation)/TILLING	**** many sources
CIP	Potato	[900]	Tomato	[100]	carbohydrate metabolism/glycoalkaloid s/cold stress	At least 5 available. More underway	[94,000] & 5core tissues/late blight resistance	***	**			
	Sweet potato	***	.	**	**	***	(***)			**		
	ARTCs	.	.	.	.	.	.	.	.	.	.	.
	(Quinoa)	.		.	.	.	.	.	.	.	.	.
IITA	Musa	.	.	.	.	.	.	.	.	***	.	.
	Cassava	(****)	.	***	***	.	*	.	.	*	.	.
	Yam	***	.	11	**	.	0	.	.	.	.	.
	Cowpea	**	.	***	***	(*)	[45]	.	.	*.	.	** *V. vexillata*
	Cocoa	[372]	.	[200] and more available	.	10x under production at CIRAD	.	.	.	.	.	.
	Tropical maize	.	Rice	.	.	.	[see below]	.	.	.	.	.
CIMMYT	Maize	[5-7,000]	Rice	[1,800]	drought acid soils cold stress	(****)	[167000]	Collab with Pioneer		***	**T-DNA	
	Bread wheat	[1,500]	Rice	[600]	drought	Several A, D, AB, and soon ABD genome libraries]	[190,000]			****		
ICARDA	Durum wheat	[1000]	Rice	[400]	drought	(****)	[2,000 + most of the 6x ESTs]		.	.	.	
	Barley	(****)	Rice	[600]	drought	Several	[247,000]	**	.	****	.	
	Lentils	60	Medicago	?	drought cold stress	(****)	.	.	.	***	.	
	Faba bean		Medicago	.		.	.	.	.	.	.	
	Kabuli chickpea		Medicago	.		**	.	.	.	.	.	***C. reticulatum*
	Forage legumes		Medicago	.		.	.	.	.	.	.	
ICRISAT	Pearl millet	250	Rice	73 [+more unmapped)	seedling heat, terminal drought, insoluble P aquisition	3x Tift23DB leaf	0 (but salinity stress ESTs under invetsigation			**	**mutation	
	Peanut	[117] +[375 in wide cross]	Medicago	0 (but 310 unmapped)	Drought, foliar disease resitance	Non e	0	.	.	***	.	several
	Chickpea	76	Medicago	76	drought	8x	**drought (roots)	.	.	**	.	*C. reticulatum*
	Pigeon pea	*	Soybean	** (but 10 unmapped)	.	.	.	.	.	**	.	*P. sericeus*
	Sorghum	[3000]	Rice and other major cereals, bufflegrass, bermuda grass	300 [+more unmapped] & 220 pending from ICRISAT	Staygreen, Al toxicity	[3 libraries - 2 BTx623, *S. propinquum*]	[85,000]	.	.	**		*S. propinquum* and others

Key - resources

* Planned
**In progress
***Basic
****Advanced

Key - transformation

*Possible
**Routine
***Efficient
****Very efficient

() developed elsewhere
? Some doubt about availability

Legume crops
Cereals
Roots & tubers

Notes

Maps, approx. numbers of RFLPs, SSRs, morphological etc points only. AFLP, ISSR, DAF and RAPD markers are excluded

SSRs, nos of publicly available mapped markers