DRAFT

US-INDIA KNOWLEDGE INITIATIVE ON AGRICULTURE

INDIAN PROPOSAL

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ACRONYMS

AAU, Anand	Anand Agricultural University
AAU, Jorhat	Assam Agricultural University
AGI	Arizona Genomics Institute
AHRD	Agricultural Human Resource Development
AI	Avian Influenza
ANGRAU	Achryan N.G.Ranga Agricultural University
APEDA	Agricultural & Processed Food Export Development Authority
ARS	Agricultural Research Service
BARC	Bhabha Atomic Research Center
BAU	Birsa Agricultural University
BCKVV	Bidhan Chandra Krishi Viswavidyalaya
BHU	Banaras Hindu University, Varanasi
BT	Blue Tongue
CA	California
CARI	Central Avian Research Institute
CAU	Central Agricultural University
CAZRI	Central Arid Zone Research Institute
CCS HAU	Chaudhary Charan Singh Haryana Agricultural University
CFTRI	Central Food & Technological Research Institute
CGWB	Central Ground Water Board
CIAE	Central Institute of Agricultural Engineering
CIBA	Central Institute of Brackish-water Aquaculture
CICR	Central Institute of Cotton Research
CIFA	Central Institute of Fresh-water Aquaculture
CIFE	Central Institute of Fisheries Education
CIFRI	Central Inland Fisheries Research Institute
CIPHET	Central Institute of Post-Harvest Engineering & Technology
CIRCOT	Central Institute for Research on Cotton Technology
CMFRI	Central Marine Fisheries Research Institute
CPCB	Central Pollution Control Board
CRIDA	Central Research Institute for Dry Land Agriculture
CSAUA&T	Chandra Shekar Azad University of Agriculture & Technology
CSF	Classical Swine Fever
CSKHPKV	Ch. Sarwan Kumar Krishi Vishvavidyalaya
CSSRI	Central Soil Salinity Research Institute
CSWCRTI	Central Soil & Water Conservation Research and Training Institute
CTCRI	Central Tuber Crops Research Institute
DFRL	Defence Food Research Laboratory
DNA	Deoxyribose Nucliec Acid
DSS	Decision Support System
DU	Delhi University
ELISA	Enzyme Linked Immuno-Assay
ES	Embryonic Stem
EST	Expressed Sequence Tags
FAO	Food & Agriculture Organization
FMD	Foot & Mouth Disease
GBPUAT	Govind Ballabh Pant University of Agriculture & Technology
GIN	Gastro-intestinal Nematode
GIS	Geographic Information System
GM	Genetically Modified
GMO	Genetically Modified Organism
HRD	Human Resource Development
IARI	Indian Agricultural Research Institute
ICAR	Indian Council of Agricultural Research
RCER	Regional Center for Easterern Region
NEHR	North-East Hill Region
ICRISAT	International Crop Research Institute for Semi Arid Tropics
ICT	Information Communication Technology

IFPRI	International Food Policy Research Institute
IGKV	Indira Gandhi Krishi Vishwavidyalaya
IIHR	Indian Institute of Horticulture Research
IIPR	Indian Institute of Pulse Research
IIT	Indian Institute of Technology
IIVR	Indian Institute of Vegetable Research
ILRI	International Livestock Research Institute
IPM	Integrated Pest Management
IT	Information Technology
IVRI	Indian Veterinary Research Institute
TNAU	Tamil Nadu Agricultural University
JNKVV	Jawarharlal Nehru Krishi Viswavidyalaya
KAU	Kerala Agricultural University
KIA	Knowledge Initiative in Agriculture
KKV	Konkan Krishi Vidyapeeth
KSU	Kansas State University
KVAFSU	Karnataka Veterinary & Fishery Science University
LEPA	Low Energy Precision Application
LESA	Low Elevation Spray Application
MAFSU	Maharashtra Animal Science & Fishery University
MAHYCO	Maharashtra Hybrid Company
MAP	Medicinal & Aromatic Plants
MAS	Marker – Assisted Selection
MAU	Marathwada Agricultural University
MBV	Monodon Baculo Virus
MESA	Medium Elevation Spray Application
MIT	Massachusetts Institute of Technology
MPKV	Mahatma Phule Krishi Vidyapeeth
MPUAT	Maharana Pratap University of Agriculture & Technology
MSU	Michigan State University
NAARM	National Academy of Agricultural Research Management
NARP	National Agricultural Research Project
NARS	National Agricultural Research System
NATP	National Agricultural Technology Project
NBAGR	National Bureau of Animal Genetic Resources
NBFGR	National Bureau of Fish Genetic Resources
NBPGR	National Bureau of Plant Genetic Resources
ND	New Castle Disease
NDDB	National Dairy Development Board
NDRI	National Dairy Research Institute
NIN	National Institute of Nutrition
NRCMAP	National Research Center on Medicinal & Aromatic Plants
NRCPB	National Research Center on Plant Biotechnology
OSU	Ohio State University
OUAT	Orissa University of Agriculture & Technology
PAU	Punjab Agricultural University
PDKV	Panjabrao Deshmukh Krishi Vidyapeeth
PGC	Primordial Germ Cells
PUFA	Poly-unsaturated Fatty Acids
QTL	Quantitative Trait Loci
RAU (Pusa)	Rajendra Agricultural University
RAU, Bikaner	Rajasthan Agricultural University
RNA	Ribose Nucleic Acid
SAU	State Agricultural University
SDSS	Spatial Decision Support System
SGWB	State Ground Water Board
SKUAT	Sher-e-Kashmir University of Agriculture & Technology
TNVASU	Tamil Nadu Veterinary & Animal Sciences University
UAS, Bangalore	University of Agricultural Sciences
UAS, Dharwar	University of Agricultural Sciences

US	United States
USA	United States of America
USAID	United States Aid for International Development
USDA	United States Department of Agriculture
WBUA&FS	West Bengal University of Animal & Fishery Science
WSSV	White Spot Syndrome Virus
WTCER	Water Technology Center for Eastern Region
WTO	World Trade Organization
YSPUHF	Yashwant Singh Parmar University of Horticulture & Forestry

CONTENTS

US India Knowledge Initiative on Agriculture (KIA)

Indian Proposal

Executive Summary

The contribution of US Land Grant Universities during 1960's in transforming India's National Agricultural Research System has been well recognized as it greatly helped in ushering the green revolution in the country. The collaboration has also enriched American Institutions with international insights and networks. The process of technology led agricultural growth continued in the subsequent decades which enabled India to move towards white, yellow and blue revolutions, thus ensuring self reliance in food security.

The global agricultural scenario has been witnessing a sea change for the last two decades. New issues such as global warming and climate change, new pests & diseases, natural resource depletion and degradation, house hold nutritional security, slowly growing farm profitability, food safety, trade competition etc. have arisen. The involvement of private sector in agricultural research, education and training is yet another development which need to be harnessed. Thus, agriculture has become more global in its reach, more complex in trade and exchanges, more technologically grounded and ever more challenged with balancing sustainability, productivity, profitability and inclusiveness. In order to address these issues, a paradigm shift is called for in human resource development, research, technology generation, technology dissemination and commercialization. The USA and India being leaders in different fields of science and technology and with rich past experience of R&D collaboration for agriculture development have tremendous scope to compliment each other's capabilities by forging new strategic alliance in key areas. To that end, the Ministry of Agriculture, Government of India and the United States Department of Agriculture jointly decided to promote a new, a US-India Knowledge Initiative on Agriculture Education, research, service and commercial linkages.

In pursuance of this decision, educational and research areas were identified through wide consultations for possible coverage under KIA. The KIA Board discussed the areas and decided four priority areas, (i) namely, human resource and institutional capacity building, (ii) agri-processing and marketing, (iii) emerging technologies and (iv) natural resource management. In the short run, the Board agreed to concentrate on the four themes namely, (i) education, learning resources, curriculum development and training, (ii) food processing, use of byproducts, and biofuels, (iii) biotechnology and (iv) water management.

In the first theme, reorientation of teaching methodologies, course curricula, interaction with industry, use of new ICTs, developing and using new learning resources are emphasized to enhance quality of teaching, education and research. Inservice training, group training, faculty exchange, post-doctoral programmes, workshops, consultancy, public-private sector partnership, industry-academia interface workshops etc. are included under this theme. In the second theme, under food processing, advanced extraction and extrusion processing technologies, high pressure processing, use of membrane technology, modified atmosphere packaging, and electronic radiation technologies are emphasized. Similarly, under by-product utilization, extraction of products of nutraceuticals, pharmaceuticals, cosmetic and pesticidal values from agricultural wastes and by-products are emphasized. Under bio-fuel, advanced technologies for production of fuel alcohols from agricultural biomass and thermo-chemical conversion of biomass into fuel oils are emphasized. Under theme three on biotechnology, strategic alliance in genomics in crops, animal and fishes, molecular breeding in crop and animals, development of transgenic crops and animals, molecular approaches for plants and animal health protection and quality assurance, value addition and safety of food products are emphasized. Under theme four on water management, sustainable use of ground water resources, water quality management and remediation, use of modern tools in water management and assessment and management of agricultural droughts are advocated.

The expected gains from the initiative are enormous and they include reinvigorated educational system with trained human resource and re-oriented agricultural research system contributing to enhanced productivity, quality, profitability, income, employment and better input use efficiency.

In respect of critical activities under various themes, select Indian and American institutions are identified for alliance keeping in view their strength and complementarities.

The budget to implement the initiative from the Indian side is projected for a period of three years. The estimated total budgetary implication of the whole initiative is Rs 3500 million comprising Rs.650 million for HRD, Rs.450 million for agro-processing, by-product utilization and bio-fuel, Rs.2145 million for biotechnology and Rs.255 million for water management.

Summary of the proposed Tentative Budget

(Rs in million)

Sr. No.	Activity	Budget
A	**Education, learning resources, curriculum development and training**	**650**
B	**Food Processing, Use of byproducts and bio-fuels**	**450**
C	**Biotechnology**	**2145**
D	**Water Management**	**255**
	Total	**3500**

BACKGROUND

The contribution of US Land Grant Universities during 1960s in transforming India's National Agricultural Research System (NARS) has been well recognized as it greatly helped in ushering the Green Revolution in the Country. The collaboration has also enriched American Institutions with international insight and networks. The process of technology-led agricultural growth continued in the subsequent decades heralding white, yellow and blue revolutions, leading to self-reliance in food security. This has been facilitated through Indian NARS which is one of the largest systems in the World comprising 47 Central Institutes, 5 National Bureaux, 12 Project Directorates, 32 National Research Centres and 91 All India Coordinated Research Projects and 45 Agricultural Universities.

The global agricultural scenario has been witnessing a sea change for the last two decades. An entirely new set of issues, such as global warming and climate change, new pests and diseases, natural resource depletion and degradation, household nutritional security, slowly growing farm profitability, food safety, trade competition, etc. have arisen. These offer exciting challenges and opportunities that require development and application of new knowledge and frontier technologies in agriculture that are cost and time effective. In other words, agriculture has become more global in its reach, more complex in trade and exchanges, more technologically grounded and ever more challenged with balancing sustainability, productivity, profitability and inclusiveness. In order to address these issues, a paradigm shift is called for in Human Resource Development (HRD), research, technology generation, technology dissemination and commercialization.

In this endeavour the conventional research approaches need to be supplemented by the cutting edge technologies requiring multi-disciplinary and multi-institutional inputs. The USA and India being leaders in different fields of science and technology and with rich experience of earlier R&D collaboration for agricultural development, there is a tremendous scope to complement each others capabilities by forging new strategic alliance in key areas of HRD, agri-processing and marketing, emerging technologies, niche areas, natural resource management etc. In this context, both the countries realize the importance of active participation of private sector. In the globalized world, no country can remain isolated and therefore collaboration and partnership will lead to win-win situation. To that end, the Ministry of Agriculture, Government of India and the United States of Department of Agriculture jointly declared their desire to promote a new, "US-India Knowledge Initiative on Agricultural Education, Research, Service and Commercial Linkages".

In pursuance of the joint declaration, several deliberations were held among ICAR senior officers, select Vice-Chancellors of SAUs, Directors of National Institutes, representatives of APEDA, private organizations and other stake holders, in which educational and research areas were identified for coverage under US-India Knowledge Initiative on Agriculture (KIA). These were discussed by the Joint Indo-US Board on KIA in Washington from December 15-16, 2005 and the Board prioritized four key areas as shown in box below:

<u>A. Human Resources and Institutional Capacity-Building (Cross cutting areas)</u> **a. Education, learning resources, curriculum development and training** b. R&D, commercialization c. IPR, biosafety, food safety, investment conditions, and policy and regulatory frameworks <u>B. Agri-Processing and Marketing</u> **d. Food processing** **e. Use of by products and bio-fuels** f. Post-harvest management/value addition g. Food Marketing, cold-chain/product handling	<u>C. Emerging Technologies</u> **h. Biotechnology** i. Nanotechnology j. Nutraceutical k. Vaccines and diagnostics l. Precision farming m. Bioinformatics and information technology <u>D. Natural Resource Management</u> **n. Water management** o. Soil and management p. Climate change q. Air quality r. Waste management

In the short run, among the four areas, the Board agreed to concentrate on the four emboldened themes viz. (i) Education, learning resources, curriculum development and training, (ii) Food processing and use of byproducts and bio-fuels, (iii) Biotechnology and (iv) Water management.

The selection of the four themes in the short run as briefly elaborated below reflect their strategic importance to both the countries in terms of challenges and opportunities to accelerate the process of sustainable agricultural transformation.

To meet the contemporary and futuristic challenges, technically trained human resource in scientific advances and their successful application assumes special significance. Re-orientation of teaching methodologies, course curricula, interaction with industry, use of new ICTs, benchmarking with international standards, developing and using new learning resources including digital learning resources to enhance the quality of teaching, training and research have become critical. Harnessing the complementarities between Indian and US institutions in both public and private sectors in HRD is central to achieve the goal of the whole KIA.

Agro-processing, byproduct utilization and biofuel production & use is yet another rich area to enhance marketability, nutrition, income, employment besides enormous environmental and ecological gains. Food processing is a sun-rise sector and there is immense scope for technological refinement and up-gradation for large scale adoption / commercialization. Both India and US have mutual interest in technological upgradation and exploring new markets in newly emerging health and functional foods. Technological advances to obtain biofuels from non-edible oils and setting up of power plants using large quantity of available biomass is yet another uncommon opportunity under this initiative. The private sector will have an important role in these activities.

Under emerging technologies, the role of biotechnology in enhancing yield, nutrition and processing quality, safety, shelf life, stress-biotic and abiotic tolerance are critically important. Strategic alliance in genomics, molecular breeding, development of transgenics, use of molecular approaches and quality assurance and safety of food products in plants animals and fishes are the specific areas where the benefits will be enormous. The private sector has also a significant role to play with particularly for commercialization of technologies.

Water availability for agriculture is declining fast and is predicted to reach the stress level soon. Enhancing the water use efficiency at all levels has to be achieved through raising water use efficiency, effective use and reuse / recycling of poor and marginal quality water, use of modern tools and technologies in water management and assessment and management of agricultural drought.

Thus strategic alliance in four themes as stated above will contribute to enlightened human resource, enhanced income and employment, greater productivity, profitability, quality and better input use efficiency.

The tentative work plan in these agreed areas with necessary specificities and estimates to allow other players to act on them are provided in the succeeding sections.

SECTION A. EDUCATION, LEARNING RESOURCES, CURRICULUM DEVELOPMENT AND TRAINING

A 1. Background

India, since independence, followed a path of science-led growth of its agriculture and agricultural education was placed in the forefront. A comprehensive educational system has been evolved for building human resource that could undertake location and situation specific research and transfer its results to improve productivity, profitability and resilience in agriculture. Not only the educational system was patterned on the Land Grants Colleges of the USA, but faculty was also trained in the US universities through a joint Indo-US programme. This initial critical mass of faculty/scientist played a key role in further preparing technically qualified human resources that set the direction and course of events leading to Green Revolution initially and while, blue and yellow revolutions subsequently.

The first structured HRD efforts in agriculture were undertaken during 1960s and early 1970s, when about 25 SAUs functioned under US Land Grant Pattern. The SAUs like GBPUA&T, Pantnagar and JNKVV, Jabalpur had collaboration with University of Illinois under USAID programme for faculty upgradation undertaken through training in USA. Subsequently, some universities continued to have Indo-US HRD programmes under specific MOUs. Of late, under AHRD and NATP, another structured HRD was undertaken in the ICAR-SAU system. As part of AHRD programme, training was carried out in 28 countries including US. As many as 389 fellowships and 55 study tours were provided for training faculty in various US universities. Further, 264 faculty/scientists were trained under NATP in USA and other countries.

Agriculture in India happens to face several constraints and challenges especially in the areas of natural resource management as well as for application of modern technologies to achieve reduction in cultivation cost, lowering of the adverse environmental impact, better health management and value addition. Both India and United States have recognized that only peace and prosperity in all sections of the society can ensure endurable democracy. So also if agriculture lags behind it has implications in the progress of industrial and global growth. It was felt by the concerned authorities of both the countries that there is need to revive the collaboration in agriculture in crucial areas such as HRD, agri-processing, emerging technologies and natural resource management. There is need to create much larger scientific pool in this area who are conversant with the latest technological development and application initiatives. India has the advantage of having rich biodiversity and one of the largest National Agricultural Research System (NARS) in place which can be easily activated to harness the benefits emanating from the proposed US-India collaboration. To ensure maximum benefits, it will be important that structured temporal and spatial training programmes are developed in focused high impact areas with the Institutions identified based on relevance of their mandate and potential strength. The trainings are to be in sufficient numbers to create critical human resources in different institutions. It is envisaged that these centres are modernized and equipped adequately so that once the human resources are developed by various mode of trainings and international exposure, there will be scope for them to take up challenging problems whose solutions need their acquired expertise. As the HRD is proposed to take place across the disciplines, either within the project or outside, provision have been made to create enough infrastructure for strengthening of education, extension and commercialization beside R & D.

A 2. Rationale

With the plateau in productivity of principal food crops and declining factor productivity, India aims at second Green Revolution. Accordingly, emphasis is being laid on approaches that move from: (i) piecemeal to holistic solutions, (ii) commodity to production systems, (ii) applied to basic and strategic research, (iii) mono-disciplinary to interdisciplinary research, (iv) single institution to cross organization and trans country working and (v) home-based consumer to market-driven agriculture. In order to meet these contemporary and futuristic challenges, technically qualified and trained human resources are needed. An appropriate agricultural education portfolio supportive of this requirement needs to be reengineered. Agricultural education with new look should also link with various stakeholders either depending on agriculture as a means of livelihood or pursuing economic activities dependent on agriculture. In the changed scenario, quality of agricultural education has to develop for global competitiveness. In pursuance of these endeavors, the first requirement would be to develop a class of highly motivated and competent faculty that inturn can churn out top quality professionals relevant and useful to sustainable development of agriculture in all its aspects – academic, economic, social and environmental. Enhancement in the professional capability alone will not be adequate until teaching methodologies and course curricula are also reoriented and refined. The promotion of industry-academia interaction shall further enhance the relevance of education and research in economic growth of the country in changing scenario.

In the past, the ICAR jointly with State Agriculture Universities (SAUs) and others has taken a number of steps for institutionalising reforms on streamlining and improving agricultural education in the country. Serious efforts have been launched on strengthening quality and relevance of agricultural education through in-service training and necessary infrastructure development. A well-conceived and comprehensive Accreditation System has been set up to ensure quality of education. Other major improvements include: introduction of new courses particularly on skill and entrepreneurship development and information and communication technology, common entrance test for reducing inbreeding, scholarships and fellowships to attract meritorious students, best teacher awards to cultivate excellence in teaching, capacity building for faculty improvement, renovation and development of laboratories, instructional farms and libraries, introduction of rural agricultural work experience to engage students in learning about farmers and real life agriculture, setting up of education technology cells and manpower need assessment for agriculture. It has unquestionably helped in removing some inconsistencies in educational norms and standards necessary to sustain uniformly high quality of agricultural education in the country.

The proposed US-India Initiative is expected to compliment and accelerate these efforts.

A 3. Objectives

In line with the above rationale, the joint programme will have the following objectives:

- To enhance quality and relevance of higher education through reorientation and refinement of course curricula, learning resources and delivery processes.
- To develop and enhance human capacity in the emerging areas through training and faculty exchange
- To promote industry-academia interaction to enhance relevance of education and research on a changing time scale.

A 4. Conceptual Framework

Agricultural education in India needs to be globally competitive. This calls for enhancing usefulness of agricultural education in terms of: (i) employability of the graduates, (ii) developing human resources to fulfill country's commitments towards millennium development goals, and (iii) improving quality of life through sustainable development. The contribution of US collaboration in the past to the HRD activities are widely acknowledged. The present programme lays focus on collaboration to mutually benefit by strengthening select niche areas of cutting edge technologies towards global competitiveness.

With the rapid change in technology environment, there is demand for developing graduates to harness science and technology. This calls for new courses as per changing market demand and new mode of delivery with effective use of electronic media. Efforts will be made to modernize course curricula and methods of delivery i.e., moving from teaching to learning. This would bring about substantial improvement in the tools and techniques of imparting education in that teacher and taught are more interactive and learning is for up scaling the skills in real life situations.

A critical mass of faculty and scientists in pre-identified subject domains and niche/strategic/emerging areas is required to be developed through, post-doctoral programs, faculty exchange, trainings, workshops etc. This select faculty and scientists in turn would serve as catalyst for further change and improvement. The proposed faculty and scientist exchange would reinforce the education and research by offering need based courses employing innovative delivery mechanisms and initiating research with international relevance.

The new information and communication technologies (ICTs) would enable reaching the un-reached anywhere any time and at competitive cost. Large mass of youth could be reached through employment oriented training and education programs in distance mode. The NARS institutions have large number of successful experiences to share with youth and the new ICTs would provide the means to share them effectively with the end users. Effective exploitation of this, requires exposing faculty and scientists to the ICT experiences to develop need based entrepreneurship oriented programs. Effectiveness of dual mode delivery of education and learning (conventional classroom and open and distance mode) would also need to be explored and emphasized.

There is need to develop learning resources. Faculty and scientists need to be trained to develop resources using multimedia, web based technologies and in transmission and retrieval of digital resources. The digital resources can be made available across NARS. Access to digital learning resources would enhance quality of teaching, education and research across the NARS institutions.

A 5. Activities:

The following activities are proposed:

i. Trainings

- **Inservice Training:** It will be meant to expose the faculty and scientists to new developments in the niche/emerging/cutting edge areas. The duration of the training shall be upto 6 months. The USA is expected to facilitate the trainings by extending the local hospitality, and ensuring access to the training facilities

- **Group Trainings:** Five such trainings shall be undertaken in India in the identified areas. The US to facilitate the training by providing access to training material and services of the scientists for imparting training in India.

ii. Faculty Exchange

- **Participation in collaborative teaching/research:** The faculty members from either side will be invited for participation in teaching and/or collaborative research. The duration of such exchange visits shall be up to 16 weeks.
- **Team visits:** One visit per year of a team consisting of up to 10 senior faculty members/senior education managers/officers shall be undertaken up to 2 weeks. These visits will provide an opportunity to the select said

functionaries of the select University /institutions to study the methodology in curriculum development in new areas, curriculum delivery, quality assurance, learning resources, field demonstrations, commercialization of technologies, regulatory and policy frameworks, science/tech/biotech parks etc.

- **Post-Doctoral Programmes:** The Indian scientists/faculty preferably young persons shall be sponsored for post-doctoral programmes in USA up to two years in identified areas only.

iii. Workshops:

- **Stocktaking and programme planning:** The periodic joint workshops shall be held for stock taking and programme planning. These workshops will be held in alternate years in India and USA.

iv. Consultancy:

- Need based services of the Consultants shall be availed. The cost of such consultancy shall be borne by the beneficiary country.

v. Public Private Sector Partnership:

- **Joint trainings:** Need based joint trainings shall be organized so as to focus HRD efforts on areas of mutual interest and benefits to these sectors.
- **Professorial chairs:** The industry/private sector sponsored chairs to be created for R&D on strategic/niche areas. This will help in close collaboration between public and private sectors which in turn will lead to commercialization of technologies at a faster pace.
- **Industry-Academia Interface Workshops:** Each year, faculty and industries from both the countries will be invited for Workshop to devise strategies by which synergies can be induced to orient education and research contributing to the economic growth. This workshop will be alternately held in India and USA.

The salary, travel cost, per diem and, health insurance in respect of trainings and faculty exchange to be borne by the sponsoring country. The host country is to provide access to facilities and needed logistic (boarding, lodging and local transport) supports. In respect of workshops, the host country is to meet the expenses related to organization of the event and the sponsoring country to meet the travel cost. As far as post doctoral programmes are concerned, the sponsoring country has to meet the salary and the travel cost whereas the fellowship and logistics (boarding, lodging and local transport) to be provided by the host country.

A 6. Key Areas

Areas identified for the above activities along with the number of slots for the first phase are as under. These areas will be reviewed in the joint workshop every year.

Sr. No.	Area/Sub Area	No. of slots
I	**Education, learning resources, curriculum development and training:** Curriculum development, instruction design and development, web-based instructions, multi-media, distance learning, teaching technology, computer based instructions, multi-media modules for instructions, on-line examinations, network based instructions, management of agriculture education, quality assurance, library information system and Database Management of bio-resources	100
II	**Food Processing, byproduct utilization and bio-fuel:** Extraction Technology, Controlled and Modified Storage, Extrusion Technology, Food Packaging, Food Quality and Safety, Fermentation & Enzyme Technology byproducts utilization. Gasification of Biomass & Generator Technology.	65
III	**Biotechnology:** Fundamental and Comparative Genomes, Prion Disease Diagnosis, , Bioinformatics, High throughput Gene Expression Analysis Technologies (Microarray), Plastid transformation in plants, Reverse Genetics for Viral Genome Manipulation, Molecular Diagnostics and Vaccines, Host Pathogen Interaction, Bioagents, Signal Transduction, Allele Mining, Gene Therapy and Gene Silencing.	110
IV	**Water Management:** Ground Water Management, Water Quality Management and Remediation, Use of Modern Tools in Water Management, Rain water Management for Enhancing Productivity and Livelihood. Water Poverty Mapping, Marine Population Dynamics.	95
V	**Other Niche Areas:** Surveillance, Forecasting and Dynamics, Climate Change, Methane Gas Emission, Soil Biota, Arsenic Management, Bioremediation, Carbon Sequestration and trading, Remote Sensing/GIS, Nanotechnology Application in Biosciences, Exploitation of Apomixis, Host Pathogen interaction, Nutrient Budgeting, Immunodiagnostics, Prophylactics, Trout, Finfish and Catfish Production Systems. Gene Bank Management, IPM and Resource Conservation Technology, species recovery and rehabilitation in natural habitat. Protected Farming. Bio-colours, Bio-Prospecting, Bio-agents, Processing and Quality Assessment of MAP and Valuation of Biodiversity Technology incubators, IT/BT/Science Parks, Trade and Marketing, Agribusiness Management, computer aided design, ergonomics and safety. IPR, Bio-safety, quarantine and Food Safety	130

A 7. Tentative Budget

(Rs in million)

Sr. No.	Activity	
1	Training	310
2	Faculty exchange	250
3	Worskhops	25
4	Consultancy	15
5	Public Private sector partnership	50
	Total	**650**

A 8. Partners:

USA:

Cornell State University, Texas A.M. State University, Iowa State University, Michigan State University, University of Illinois, Purdue University, Ohio State University, University of Florida, Kansas State University, Pennsylvania State University, University of California, Rutgers University, Brunswick, NJ, Fort Valley State University, Fort Valley, Georgia, University of Illinois Urbana, IL and other relevant institutions to be finalized.

India:

Considering the needs in niche/emerging/cutting-edge areas, selected institutions from the NARS (viz. agricultural universities, CAU, Deemed Universities, ICAR Research Institutes, participating private sectors etc.) will participate.

Based on the past experience in collaborative efforts with US-India initiatives, established capabilities, lead in niche/emerging/cutting edge/strategic research, future potential, the capability enhancement of different institutions of Indian NARS shall be undertaken in phased manner The probable partners in Universities/Institutions from USA and India for HRD are given in Annexure-A 1.

A 9. Baseline information:

The historical perspective of agricultural education in India is well documented. It is obvious that the USA has been a major collaborator with India in development of agricultural human resources. In different spells under different programmes a large number of young scientists faulty were trained in USA who on return became leaders and senior faculty members in their respective disciplines which helped in development of India’s National Agricultural Research System (NARS). Mention is made of TCM, USAID collaboration towards establishment of State Agricultural Universities in number of states. A number of Indian scientists were trained and exposed in USA under Indo-US Sub Commission on Agriculture on Plant Genetic Resources, Soybean Processing and

Utilization and Agro-Forestry. Subsequently, Indian scientists got training and exposure under National Agricultural Research Project (NARP), AHRD and National Agricultural Technology Project (NATP). American scientists and faculty members also visited India under some of these collaborative programmes who guided and worked with the Indian scientists.

Agricultural human resource development programmes have made significant impact on Green Revolution, and subsequent White, Blue and Yellow Revolutions would not have been possible but for human resource development initiatives of the Council in the past and establishment of SAUs. However, excepting the structured efforts in 1960s, the collaboration with US had been isolated and on limited scale. Hence, it is necessary that new initiative is taken by involving all relevant institutions so that the needed advances are made in the identified, emerging/cutting-edge areas having different stake holders. The present initiative will provide the needed fillip in this direction.

A 10. Expected Outcomes/Deliverables

a. Outputs/Deliverables:

- Over 500 faculty members and scientists are expected to get trained in emerging/niche areas under this programme. enhancing thereby the quality of education and research in the first phase.
- It is expected that new programmes/courses will be initiated.
- Significant modernization and upgradation will be effected in the ongoing curricula and their delivery.
- A large number of joint projects and academic programmes (more then 200) are expected to be formulated.
- The use of electronic media will become prevalent in transfer of knowledge across the system.

b. Outcome:

- Enhanced quality of agri-education
- Increased use of educational technology tools
- Enhanced number of trained personnel multiplied by sharing knowledge and skill to spread effect in the emerging and niche areas
- Improved delivery of innovative programmes reaching the un-reached
- Overall socio-economic up-liftment in agrarian sector
- Internationally competitive agriculture
- Quality improvement in agri-products and services.
- Graduates with more social responsiveness on issues such as environment, equity, poverty alleviation, etc.
- Overall capacity building on NARS by improving efficiency and effectiveness of education system.

Annexure A.1

Tentative List of Partners for HRD

Sr. No.	USA Institutions	Indian Institutions
A.	**Education, learning resources, curriculum development and training**	
	University of Illinois Cornell State University Texas State University Michigan State University Pennsylvania, State University, Iowa State University, Ohio State University	NAARM, IARI, IVRI, NDRI, CIFE, GBPUAT, JNKVV, PAU, OUAT, TNAU, CSAUAT, MPKV, UAS(B), ANGRAU, AAU, MPUAT, KKV,KVAFSU, KAU, TNVASU,CAU, RAU (P), AAU (A), BAU, AAU (J), SKUAT (S), CSHPKV
B.	**Food Processing, use of byproducts and bio-fuels**	
	Cornell University, Ithaca Illinois Institute of Technology Iowa State University of IA Kansas State University University of Texas University of Rhode Islands Michigan State University, WRRC, Alabana, University of Illinois. Mississippi State University School of Marine Sciences & Technology, New Bradford (Massachusetts) Cornell University, Ithaca Florida Agricultural and Mechanical University Kansas State University Rutgers University New Brunswick, NJ	CIFT,KVAFSU,KAU, TNVASU,WBVAFS, GBPUAT, CIPHET, CIAE, PDKV, MAU, YSPUHF, TNAU, IIT (Khargpur), CFTRI, DFRL, NIN, CIRCOT, AAU-A, UAS-B, MPUAT

C.	**Biotechnology**	
	Cornell University., UAC, Davis; AGI, Arizona; NCSU, Raleigh; Univ. of Minnesota; Univ. Of Nebraska, Lincoln; Colorado State Univ., Colorado Michigan State University University of Florida Texas A & M University, University of llinois, University of Maryland, Purdue Univ.;	CIFA, NBFGR, CIBA, KVAFSU , NBFGR, CIFRI, GBPUAT, KVAFSU, CIFE, KKV, ANGRAU, UAS (D), TNAU, CCS HAU, NRCPB, MAU, IIPR, IARI, IVRI, NDRI, NBPGR, IIVR, ICAR-NEHR, MAFSU, PAU
D.	**Water Management**	
	Michigan University, Utah State University, Washington State University, University of California, Davis , Alabama State University. USDA, Ohio State University, University of Florida, Goddard Institute of Space Science, New York, University of Minnesota.	CMFRI, CIFRI, CIFE,KKV, AAU, CAU, CRIDA, GBPUAT, CGWB, IARI, MPUAT, CCSHAU, IIT (D), PAU, CSSRI, BCKVV, IIT (K), ICAR-RCER, WTCER, MPKV, CAZRI, JNKVV, IGKV, RAU (P), RAU (B), SKDAU,
E.	**Other Niche Areas**	
	Michigan State University, Texas A&M University, United State Patents & Trade Marks Office, University of Illinois Cornell University, Ithaca Florida Agricultural and Mechanical University Iowa State University Kansas State University Michigan State University Mississippi State University IFPRI, Washington North Carolina State University; Univ. of Minnesota	IARI, NDRI, CIPHET, GBPUAT, IVRI, CIAT, IIHR, UAS(B), CCSHAU, MPUAT, RAU (B), MPKVV, CIFE,NBFGR,CIFT, KVAFSU, PAU, RAU (P), TNVASU CAU, MAU, CSAUT, SKUAT (J), SKUAT (S), BAU, OUAT, MPKV, JNKVV, IGKV, BCKV, AAU (J), AAU(A), YSPUHF

SECTION B: FOOD PROCESSING, BYPRODUCT UTILIZATION & BIO-FUEL

B 1. Background

India produces about 750 million tonnes of major raw food materials of plant (650 million tons) and animal origin (100 million tons) besides natural fibres and rubber. There are post harvest losses in agricultural produces amounting to about Rs. 50,000 crores. These losses could be minimized to a great extent through appropriate commodity and location specific post-harvest technology preferably in the production catchment. Such primary processing will also facilitate employment and income generation, byproducts utilization and better quality food products. About 2% of horticultural produce is processed in India and in general, the value addition to agro-produce is at a low level of about 7% in comparison to developed and some of the developing countries where 60-70% of farm produce is processed and value added.

Efforts are being made in India in food processing and value addition and as a result, a large number of post-harvest equipment and technologies have been developed and are being used. However, some of the technologies need refinement and upgradation for large scale adoption. This requires an acceleration in our R&D efforts and commercialization of such technologies

Activities related to food processing, value addition and energy management using newer technology such as extraction, extrusion, fermentation, high pressure steriliization, membrane separation are needed to be carried out for maximizing the gains to the producers, processors, traders and consumers. This will also result in minimizing the waste and providing high quality, safe and competitively priced processed food material for ensuring desired nutrition to the consumers. The human resource who will be undertaking these activities will also need to be developed through training, exchange of visits, workshops and auditing of special courses in US.

The US is increasingly viewing India as a strategic partner in jointly developing food processing technologies and innovative products such as health and functional foods. The US is also interested in Indian food market. India too is looking towards US markets and activities in food processing sectors that will be of mutual benefits.

Scarcity and increasing cost of fossil fuels and emphasis on sustainable agro-industrial development demand for an alternate renewable sources of energy. Cultivated crop residues and biomass and non-edible oils can be used as a source for power generation and production of biofuels. The method for obtaining oil from Jatropha through transesterification process has been developed and there is need to setup a pilot plant for production of biofuels. The expertise available with US counterparts would be utilized to strengthen this activity for obtaining biofuels from non edible oils and for setting up of power generation plants using part of the 700 million tones biomass available.

The Indo-US collaborative programme will facilitate and accelerate the development of newer technologies for innovative processed and value added products from agro-produces, byproducts and enhance professional expertise of Indian scientists and knowledge base in food processing, byproducts utilization and biofuels.

B 2. Rationale

India has achieved a great success in the production of food materials but processing and value addition to these commodities are still at very low levels. The quality & safety of raw food materials and processed products need to be ensured. Further, there are post harvest losses amounting to about Rs. 55,000 crores, annually, which need to be minimized through infusion of cost effective improved processing technologies. There is a tremendous scope for developing technologies for better utilization of not only the major food crops but also to develop innovative products from high nutritious produces like, millets, legumes, fruits and vegetable, meat and fish. Strengthening of research infrastructure, undertaking collaborative/joint research activities with US stakeholders, HRD of Indian Scientists and commercialization of food processing technologies are required. While the interest of the Indian side will be to get exposed to highly equipped US laboratories, industries and marketing infrastructure, the US counterparts will also have opportunities to benefit from the knowledge generated and experience gained in the low cost yet commercially potential technologies developed under the collaboration. There are prospects of commercialization of technologies generated through joint ventures between US and Indian industries and stand alone enterprises in India.

B 3. Objectives

- Development of technology for innovative processed and value added products from plant and livestock produce.
- Development of technology for an economic utilization of agricultural byproducts.
- Development of technology for bio-fuels from agricultural biomass.
- Human resource development in critical areas of agro-processing and value addition.

B 4. Activities

i) Food Processing

- Advanced technology for extraction of oils, oleoresins, biocolours and bioactive compounds from agro-produce and byproducts.
- Advanced extrusion processing for speciality food products
- Conservation of nutrients, flavour and texture through high pressure processing technology.
- Physical separation and fractionation of liquid food constituents using membrane technology
- Modified atmosphere packaging and storage of perishable food products.
- Technology for rapid detection & control of biotoxins, chemicals contaminants and heavy metals in agricultural produce and products.
- Electromagnetic radiation for food sterilization and preservation.
- Technology for cholesterol-free milk and milk products.
- Development of bio-degradable and edible plastics from low-value starch materials and byproducts for packaging of food products.

ii) Byproduct Utilization

- Extraction of products of nutraceuticals, pharmaceuticals, cosmetic and pesticidal compounds from agricultural wastes and byproducts.
- Value addition to by-products for various end uses

iii) Biofuel

- Technology for fuel-alcohols from agricultural biomass.
- Thermo-chemical conversion of biomass into fuel-oils.

B.5 Budget estimates

(Rs in millions)

Serial No.	Activities	Budget
1	Food Processing	245
2	Byproduct Utilization	55
3	Biofuel	150
Total		**450**

B 5. Output/Outcome

- Knowledge about hidden wealth in biological materials.
- Processes & pilot plants for obtaining value added specific end products from agricultural produce & byproducts leading to new agro industrial activities generating additional employment and income.

- Availability of speciality foods and industrial raw materials that meet consumer/industrial need within India and abroad.
- Biofuel for reducing dependence on non-renewable energy sources.
- Enhanced professional expertise of scientists and knowledge base on food processing, byproducts utilization and biofuels.
- Food Processing incubation center(s) for on hand experience and entrepreneurship development, commercialization of technology, leading to enhancement in processing, value addition and minimization of post harvest losses.

Annexure I

TENTATIVE BUDGET FOR FOOD PROCESSING, BYPRODUCT UTILIZATION & BIOFUEL

Rs. in Millions

S. No.	Activities	Partners		Tentative Budget
		India	USA	
1.	**A. Food Processing** Advanced technology for extraction of oils, oleoresins, biocolours and bioactive compounds from agro-produce and byproducts	CIPHET, IISR IGKVV, CIAE, MPKV, JNKVV, CIFE	Texas A &M, Texas NRRC, Peoria	35
2.	Advanced extrusion processing for speciality food products	CIAE, UAS (B), TNAU, JNKVV, IIT, CIFT,	WRRC, Albany, CA Texas A&M, Texas	30
3.	Conservation of nutrients, flavour and texture through high pressure processing technology	CIPHET, CIAE, PDKV, CIFE, DFRL, CIFT, KVAFSU,	WSU, Washington OSU, Ohio Virginia Tech, Blacksburg Oregeon State University, Oregeon, KSU, Manhattan, Illinois Institute of Technology, Illinois	30
4.	Physical separation and fractionation of liquid food constituents using membrane technology	CIPHET, CIAE, CFTRI,	Univ. of Illinois, Illinois	30
5.	Modified atmosphere packaging and storage of perishable food products	CIAE, PAU, DFRL,	Cornell Univ. Ithaca(NY) ISU, AMES Oregeon State University, Oregeon Oklahama State Univ., Still Water MSU, Michigan, University of Tennesse, Tennesse	20
6.	Technology for rapid detection & control of	CIPHET, CIAE, TNAU, KKV,	WSU, Washington Purdu Univ. West	20

	biotoxins, chemicals contaminants and heavy metals in agricultural produce and products	NIN, PAU	Lafayette, Indiana Pen. State Univ. Pennsylvania Iowa State University, Ames	
7.	Electromagnetic radiation for food sterilization and preservation	CIAE, IIT (K), CIPHET, BARC,	WSU, Washington CU, Ithaca(NY) OSU, Ohio	25
8.	Technology for cholesterol-free milk and milk products.	NDRI, GBPUAT, IIT (K),	Pen State Univ., Pennsylvania. Univ. of Georgia, Athens	25
9.	Development of bio-degradable and edible plastics from low-value starchy produces and bioproducts for packaging of food products	CIPHET, IIT, CTCRI, CFTRI,	WRRC, Albany, CA Iowa State University, Ames School of Packaging, MSU, Michigan	30
10.	**B. Byproduct Utilization** Extraction of products of nutraceuticals, pharmaceutical, cosmetic and pesticidal values from agriculture wastes and byproducts Value addition to byproducts	CIAE, CIPHET, CIRCOT IARI, AAU (J), ILRI, NIN, NRCMAP, TNUVAS	WSU, Washington CU, Ithaca(NY) ISU, Ames	55
11.	**C. Biofuel** Technology for fuel-alcohols from agricultural biomass.	CIAE, UAS D), CCS HAU, TNAU, GBPUA&T, CIPHET, VSI,	NREL, Colorado Univ. of New Hampshire, Durham CU, Ithaca(NY)	85
12.	Thermo-chemical conversion of biomass into fuel-oils and Aneorobic digestion of crop-residues	CIAE, CIRCOT SPRERI, TNAU, MPUAT, PAU, Assoc. Engg. Works, Tanaku, A.P.	Univ. of Idaho, Idaho NREL, Colorado, CU, Ithaca(NY) Oklahama State Univ. Still Water,	65
	TOTAL			**450.0**

SECTION C. BIOTECHNOLOGY

Biotechnology provides an opportunity to convert bio-resources into economic wealth. National agricultural biotechnology policy of India envisages the economic well being of farm families, food security of the nation, health security of the consumer, protection of the environment and the security of national and international trade in farm commodities. In the first phase of the KIA following programs in biotechnology are proposed for capacity building and infrastructure development that are relevant for harnessing genetic potential and for maximizing the productivity of agriculturally important plant, animal and fishery resources.

C 1.Genomics in crops, animals and fishes
C 2.Molecular breeding in crops and animals
C 3.Development of transgenic crops, animals and fishes
C 4.Molecular approaches for plant and animal health protection.
C 5.Quality assurance, value addition and safety of food products

C 1. Genomics in Crops, Animals and Fishes

i. Background

Recent advances in the area of genomics have provided means to understand the structure and function of large number of genes that constitute the genomes of higher plants and animals. There are several recalcitrant problems in agriculture, which can be tackled using technologies generated through genomics that will make the agricultural sciences more rewarding and economically viable. The genomics research has already made an impact in the fields of human medicine and nutraceuticals, and more recently it has led to the discovery of several genes of agronomic importance in rice e.g. earliness, grain number, dwarfness, disease resistance, etc. Partnerships among select laboratories in USA and India would facilitate making agriculture a scientific, predictable and remunerative industry by harnessing the power of genomics.

India is the largest producer and consumer of pulses in the world, accounting for about 25 percent of global production, 27 percent of consumption, and 34 percent of food use (FAO). It is also the top importer, with an 11 per cent share of world imports during 1995-2001. Pulse production in India has fluctuated widely with no long-term trend, leading to a steady decline in per capita availability over the past 20 years. Since most Indian consumers have low incomes, they rely on pulses as a key source of protein. Stagnant production and increasing population has led to rising pulse prices and declining per capita consumption despite a liberal policy regime towards pulse imports. Developed nations like USA, Canada and Australia are the potential exporters of grain legumes, including pigeonpea to India due to its high demand. Pigeonpea is one of the most important pulse crops of India and a number of factors are responsible for the poor productivity of pigeonpea, including lack of improved cultivars, poor crop husbandry, pests and diseases. Fusarium wilt (*Fusarium udum* Butler) in particular, has been shown to significantly affect its production. Besides, gram pod borer (*Helicoverpa armigera*), pod fly (*Melanagromyza obtusa*), phytophthora blight (*Phytophthora drechsleri*) and sterility mosaic disease (Sterility mosaic virus) also cause substantial reduction to pigeonpea production every year. Furthermore, abiotic stresses like excess water in early stage, low water stress in the later stages and salinity also reduce pigeonpea production. Among the pulses, pigeonpea possesses maximum variability for all possible traits on account of its often cross-pollinated nature. Conventional breeding has done much but has not improved productivity of this crop substantially. The use of molecular markers provides an excellent aid for exploitation of full potential of conventional breeding .

Water buffalo is a multipurpose animal with its use for dairy, draught and meat. India with its current population of 96 million has more than half the world buffalo population and is the home of best milch breeds (Murrah, Nili-Ravi, Mehsana, Jaffrabadi, etc.). They contribute to more than 55 per cent of total milk produced in the country. Buffalo milk contains more total solids, fat, protein and less cholesterol than cow's milk. Annually about 8.7 million buffaloes are slaughtered to yield 1204 million metric tonnes of meat contributing over 44.5 percent of buffalo meat produced globally. Buffalo is an efficient converter of poor quality roughages and comparatively resistant to several tropical diseases. Of late, interest in this important species has increased in US and Europe for Mozzarella di Bufala (also known as Buffalo Mozzarella). However, full genetic potential of this species is yet to be exploited, primarily because the basic data on buffalo genome is relatively sketchy. Marker assisted selection based on functional genomics would provide boost to the productivity of buffalo.

India has rich and diverse aquatic genetic diversity. In the changing scenario, technological advancements are reducing the barriers for transferring the genes across the biological kingdom. Therefore, it becomes important that documentation of fish genetic resources extends beyond description of population and stocks to the level of genes. There is a need to develop capability and infrastructure that is equipped for large-scale genomic exploration from Indian fishery resources. At present, programme that undertakes genome research in Indian fish species is limited. Therefore, in view of the great aquatic diversity of India, initiatives are necessary to generate genomic information focus on comparative genomics and also phylogeny.

ii. Rationale

There is need to develop genomic tools to address the production constraints in grain legumes. The institutional capabilities, expertise, tools and technologies expected to develop through the US-India collaborative research will help discover new genes and mining the biodiversity that is available in pigeonpea germplasm collections for the identification of better genes. This will help to breed superior varieties for increased production and quality of grain legumes. Identification of genes for resistance to diseases, pests and environmental stresses will provide necessary tools for genetic manipulation of our livestock and poultry population for enhanced productivity. EST database provide robust sequence source that can be exploited for gene discoveries, gene function analysis and comparative genomics. A comprehensive coverage of transcriptomes of major tissues and development/ physiological stages is required for making an EST database. At present, very limited information is available on ESTs from Indian fish species. A targeted effort to explore ESTs from fish species of interest to aquaculture is necessary for genomic applications in genetic improvement programme.

iii. Conceptual framework

Phylogenetic position of a species is likely to underpin new understanding of genome evolution and comparative genomics. The proposed plan of work is intended to establish focused research base to explore tissue specific ESTs from selected crop, animal and fish species. The second component will generate the phylogenic relationship of the different species with in the taxonomic order. The integrated work on two aspects will provide scientific background so that EST base can be expanded covering more species using bioinformatic based tools. The development of a robust set of polymorphic markers is a basic pre-requisite for any molecular breeding program. There is a need to develop markers and high-density molecular map for use in pigeonpea. These in conjunction with high throughput genomic studies will lead to rapid discovery of new genes and markers for application in pigeonpea improvement. The genomic research has already made an impact in the field of human medicine and more recently in certain farm animal species like cattle, pig and poultry. The research on buffalo genomics has recently been initiated at several ICAR Institutes, SAUs and other laboratories in India. In view of the available biodiversity in buffalo and its contribution to agricultural economy, this activity is proposed to capitalize on the in house capabilities and US expertise/ resources in handling genome projects in buffalo and other farm animal species. In the proposed plan on fishes four finfish species (*Chitala chitala, Labeo rohita, Clarias batrachus, Lates calcarifer*) will be worked out to generate ESTs sequences associated with growth and muscle development. The target fish species are used for aquaculture or potential species for aquaculture and the results will provide direct input to research in aquaculture genomics for genetic improvement. These species represent taxonomic orders spread over evolutionary scale, including the primitive one. Comparison of sequences will indicate the ESTs that could be conserved over a wide spectrum of species.

a. Pigeonpea genomics

i. Objectives

- Development of resources for pigeonpea genomics including, suitable genetic stocks, cDNA and BAC libraries with fingerprints and end sequences, bioinformatics tools and databases.
- Construction of a high density molecular genetic map.
- Mapping and tagging of genes/QTLs for resistance to insect-pests and diseases, plant type (yield attributes) and grain quality traits.
- Pilot genome sequencing of 50 gene-rich BAC clones and gene annotation.
- Functional genomics for the identification of markers and candidate genes for important agronomic traits, and development of a platform for providing the "proof-of-function" to the annotated genes.

ii. Activities

- Development of F2 , RILs and NILs mapping population and mutant lines (TILLING population) for functional genomics
- Phenotyping of segregating population and genotype sets for QTL analysis, association mapping and allele mining
- Development of molecular markers and high density molecular genetic maps and consensus map (~2000 markers)
- Comparative mapping of pigeonpea genome with other legume species
- QTL analysis based on individual mapping populations and marker validation
- BAC library construction, fingerprinting, end sequencing and development of FPC and STC databases including genetic anchoring of fingerprinted BAC contigs.
- Sequencing of 50 gene-rich BACs, gene prediction and annotation
- High throughput expression analysis using cDNA and/or oligonucleotide based micro arrays.
- Association mapping and allele mining for candidate genes.
- Development of pigeonpea genomics databases e.g. EST database, genome sequence database, marker database and annotated gene database

iii. Institutional framework

(Rs. in millions)

program	Partners		Tentative Budget
	India	USA	
Pigeonpea genomics	NRCPB-IARI IIPR, UAS (D), BHU, ICRISAT, DU (S), PAU	AGI, Arizona University of California, Davis, Cornell University, New York, Texas A & M, Texas Affymatrix	600

iv. Expected output/deliverables

- Generation of genomic tools such as molecular genetic maps, molecular markers, ESTs, BAC library for genome analysis, cDNA arrays, TILLING population, transgenic system for the identification of gene function.
- Enhancement of pigeonpea breeding strategies by using molecular markers linked with QTLs or genes for yield, disease resistance and grain quality traits.
- Generation of knowledge on the evolution of grain legumes based on comparative genomics of pigeonpea and other legume species including *Medicago truncatula* and *Glycine max*
- Annotated genes and gene functions.

b. Buffalo genomics

i. Objectives

- To develop cDNA (ESTs) and BAC library resources for buffalo.
- To identify candidate genes/markers for milk yield, quality and fertility/ reproductive traits.
- To study polymorphism with respect to production and reproductive traits genes across indigenous breeds.

ii. Activities

- Development of tissue specific c-DNA libraries associated with milk yield, quality and fertility traits
- Characterization of genes encoding kappa casein and GnRH receptor in the regulation of reproduction
- Sequencing of cDNA clones to generate tissue specific genes/ESTs
- Development of BAC library resources and sequencing of gene rich BAC clones
- Characterization of important/novel genes and identification of SNPs
- High throughput expression analysis using bovine/bubaline microarray.

iii. Institutional framework

(Rs in millions)

Sub-program	Partners		Tentative Budget
	India	USA	
Buffalo genomics	NBAGR, NDRI, MAFSU, AAU-A	Iowa State University, USDA Labs at Nebraska, Maryland; Texas A& M University; Cornell University;	200

iv. Expected output / deliverables

- Genes associated with milk yield, protein quality, fertility and reproduction traits will be identified.
- Generation of EST/Gene sequence database that would help as repertoire for buffalo genome.
- cDNA and BAC library resources for future exploitation.
- Bubaline microarray would help expression profiling of economically important genes.
- Utilization of identified candidate gene markers for enhancement of buffalo productivity.

c. Finfish genomics

i. Objectives

- Characterization of tissue specific ESTs in representative species for the prioritized taxonomic group.
- Generation of molecular phylogeny information for the taxonomic group of species.
- Identification of microsatellites (type I) and other markers associated with ESTs.

ii. Activities

- Characterization of ESTs and Type I markers (Microsatellites) for fish species: Chitala (*Chitala chitala*), Rohu *(Labeo rohita),* Magur (*Clarias batrachus),* Sea Bass (*Lates calcarifer*)

- Generation and analysis of mtDNA sequences of fish species for phylogenetic relationship within the different taxonomic order.

iii. Institutional framework

(Rs. In millions)

Sub-program	**Partners**		**Tentative Budget**
	India	**USA**	
Finfish genomics	NBFGR, CIFA, KVAFSU, TANUVAS Manipur University	Auburn University	100

iv. Expected output/deliverables

- Development of expertise and infrastructure oriented to characterize the genome.
- Information base on gene tags (ESTs) related to growth and muscle build-up and type-I markers, characterized from fish species important to Indian aquaculture
- The EST base can enlarge horizontally with ESTs of more species getting characterized through cross species amplification.
- Molecular phylogeny information of important taxonomic groups of species and evolutionary relatedness of the species.
- DNA bank accessions that provide scope for retrieving genetic information and also for biotechnological applications in future.

C 2. Molecular Breeding in Crops and Animals

i. Background

Resistance to biotic and abiotic stresses of crops and animals is governed generally by quantitative trait loci (QTLs) or sometimes, major genes. Further, most of the economically important traits are also QTLs. These traits however, are not easily traceable through their phenotypic manifestation being labile to environmental conditions. Molecular polymorphism at the genomic DNA can be effectively utilized to tag these regions and to map these to specific chromosomes to enable the mobilization and pyramiding of these genes/QTLs through marker assisted selection (MAS). The procedure adds efficiency and precision to breeding the crop or animal for improved expression of the traits concerned. The development of maps and markers are of global economic importance since these can be used as knowledge base for precision breeding and targeted trait improvement.

Traits like resistance to drought, heat, salinity, toxicity to aluminum and iron need to be mapped in crops such as chickpea, mungbean and urdbean which are expected to provide protein supplement to the vegetarian population, as well as, wheat a major food crop of both India and USA. The vegetable okra also suffers these stresses. In addition, diseases like wilt caused by Fusarium and blight caused by Alternaia have been limiting productivity in several crops. Molecular breeding initiative for such traits is likely to provide a major relief, and a mapping initiative will be a useful knowledge base development for future genomics and widespread utilization.

Another important area that provides a repository to planned molecular breeding in general is utilization of available germplasm diversity to mine alleles with varying levels of trait expression. These alleles can be mined out through molecular sequence profiles of the species over the genetic variants. This activity will provide enlarged genetic variability for mobilization into cultivars through genetic enhancement and database generation, management and exploration at molecular sequence levels in the select-targeted crop plants.

Similarly, in livestock, several genes have been identified with respect to production, reproduction and disease resistance traits in cattle, sheep and goat. The advent of genetic maps of livestock species with high-density markers will enable the genetic unraveling of many of the economic traits, which are mostly polygenic in inheritance. A new generation of tools and public single nucleotide polymorphism (SNP) resources for genetic studies, specifically for candidate-gene, candidate-region, and whole genome association studies will form part of the new scientific landscape. Further, infrastructure, expertise and resource populations are not available at one place. With US partnership, a path can be developed for identification of markers relevant to indigenous livestock using comparative genomics.

India offers a large and diversified genetic resources, many of which are known to be resistant to some of the infectious diseases like foot and mouth disease (FMD), which is a highly contagious disease of cloven-hoofed animals. Integrated studies on the molecular mechanisms and diversity involved in the host-pathogen interaction can be an important component to FMD control programs world over. Targeted sharing of expertise among laboratories would be of value to generate the information base on the important diseases to support farming communities.

ii. Conceptual framework

The information generated on genomics of pigeonpea and buffalo as well as other higher organisms, will be utilized for tracking ESTs or homologous sequences related to the beneficial traits. In the first phase, molecular maps and markers will be generated in the targeted crops and animals to improve tolerance to abiotic and biotic stresses sharing the phenotyping and genotyping among laboratories in both countries. The aim is to develop genotypes which can withstand harsh environmental conditions to further improve the productivity *vis-a-vis* production. The proposed major areas comprise objectives that can complementarily be worked upon at identified institutions in the two countries according the expertise, material and functional feasibility. In the case of specific projects such as disease resistance to *Alternaria* and *Fusarium* in crops and FMD in livestock, the molecular mapping initiative could be complemented by collaborative research to understand the underlying molecular mechanisms that determine resistance/susceptibility to the diseases.

Apart from exploring the available genomic tools to enhance productivity of the targeted crops and livestock, efforts towards QTL identification using linkage dis-equilibrium or alternative methods through SNP markers will be attempted to associate exonic region of DNA to phenotypes and *vice versa*. Various diseases or abioitc stresses causing heavy losses will be targeted though these molecular techniques. The baseline data on genome diversity in the targeted crops and animals can be complemented with comprehensive molecular marker database through collaborative research on specific traits. Expertise with materials and technologies can be complemented for mutual benefit of both the nations.

In India large pedigree herds are limited where QTL identification using linkage dis-equilibrium may be difficult. Genome mapping of livestock species may be feasible by SNP analysis and whole genome scanning. The baseline data on genome diversity in indigenous cattle, buffalo, sheep, goats, horses, pigs and poultry breeds has already been generated in the country. There is a need to develop a comprehensive SNP database on indigenous cattle and other species using comparative genomics approach.

iii. Rationale

Molecular breeding for complex traits is an effective methodology of precision breeding in plants and animals. The approach enables saving of time, space and resources once the genes associated with the targeted traits are mapped and markers linked to these genes/QTLs are identified. Indo-US collaborative network approach among institutions sharing material and work elements to map the genes/QTLs for such traits in crops of importance in tropical ecologies like chickpea, mungbean, urdbean, wheat, okra and animals like cattle, pigs and poultry would provide such a focused information base. The maps and the genomic regions with the targeted genes can then be utilized as database to identify alleles for genetic variation and mobilize through markers in desirable genotypic background for genetic enhancement/disease resistance of the species.

a. Molecular Breeding in Crops

i. Objectives

- QTL/gene mapping and identification of molecular markers for yield traits, abiotic stresses like drought, heat, toxicity to aluminum & iron in chickpea, mungbean, urdbean, wheat and okra, and biotic stresses like *Alternaria* blight and *Fusarium* wilt in crops

- Allele mining for above traits
- Marker assisted selection for genetic enhancement

ii. Activities

- Development of reference mapping populations from identified genotypes to be shared among collaborating institutions for multi-location phenotyping and genotyping for the listed crops and traits
- Crop and trait-wise QTL/gene mapping through networking
- Allele mining from shared genetic resources for target traits
- Generating breeding populations and MAS for targeted traits

iii. Institutional framework

(Rs. in million)

Sub-Programe	**Parterns**		**Tentative Budget**
	India	**USA**	
Molecular breeding in crops	IARI, IIPR, IIVR, TNAU, PDKV, GBPUAT, RAU-B, NBPGR	University of Minnesota, Purdue University Cornell University North Carolina State Univeristy Kansas State University University of Wisconsin	150

iv. Expected output / deliverables

- Molecular markers linked to gene/genes for yield related traits, tolerance to the stresses
- Identification of diverse alleles for the identified traits
- Common genetic stocks for utilization as parental genetic source suited to different ecologies
- Improved lines for identified traits for yield testing and/or genetic stocks packaged with molecular markers linked to the identified genes/QTLs for MAS

b. Molecular Breeding in Animals

i. Objectives

- To identify SNPs and develop their database in indigenous cattle for genetic resistance against mastitis, pigs for growth and prolificacy, and poultry for disease resistance.
- To develop genetic markers associated with these traits from SNP information

ii. Activities

- Collection of phenotypic data and developing DNA repository from selected indigenous breeds of livestock and poultry.
- Generation of SNPs for candidate genes in these species using comparative genomics.
- Association studies of SNPs with phenotypic variations for development of genetic markers.

iii. Institutional framework

(Rs. in millions)

Sub-program	Partners		Tentative Budget
	India	USA	
Molecular breeding in animals	IVRI, CARI, AAU-A, KLDB	Iowa State University Texas A& M University USDA Labs at Nebraska, Cornell university	100

iv. Expected output / deliverables

- SNP database will be generated for candidate genes associated with economically important traits like resistance to mastitis in cattle, growth and prolificacy in pigs, and disease resistance in poultry in indigenous farm animal species.
- Genetic markers associated with economic traits in these farm animal species will further help in future breeding programs.

c. Genetic resistance of host against FMD in cattle

i. Objectives

- To elucidate the molecular mechanism of genetic resistance/ susceptibility of indigenous livestock against FMD and to develop molecular markers for its resistance.

ii. Activities

- Identification and evaluation of phenotypic and genetic markers for FMD resistance in cattle.

iii. Institutional framework

(Rs. in millions)

Sl. No.	Sub-program	Partner		Tentative Budget
		India	US	
1.	Genetic resistance of host against FMD in cattle	IVRI, TNVASU, CCSHAU,	Texas A&M, USDA-ARS, Beltsville Washington State Univ. Iowa Univ., Illinois Univ	50

iv. Expected outcome / deliverables

The project is expected to provide answers to the molecular basis of host genetic resistance to FMD in cattle. The findings could eventually help in redefining the breeding programs by incorporating pathogen resistance with production traits. Also new researchable areas like development of diagnostic tools for genetic resistance, development of transgenic animals, etc. could be explored in future.

C 3. Development of Transgenics in Crops, Animals and Fishes

i. Background

Conventional techniques of crop improvement are becoming inadequate in meeting the future challenges of food security owing to our burgeoning population, dwindling natural resource base and escalating biotic and abiotic stresses. It has, therefore, become imperative to use plant genetic engineering tools for complementing the conventional crop improvement technology.

In India, majority of the crops suffer due to various biotic and abiotic stresses, and consequently yields are adversely affected. Farmers spend considerable financial and labor resources for countering the crop losses associated with insect-pests and diseases. Similarly, more than 60% of the total cultivated area is rain-fed in India, and a 30-40% reduction is registered in crop yields due to drought/salinity stresses. Therefore, development of crops that have an inbuilt resistance to biotic and abiotic stresses would help to increase crop production. Genes conferring resistance to important pests/diseases or those imparting tolerance to drought/salinity stresses are now available for developing transgenic crops. In addition, the uptake and utilization efficiency of micronutrients need to be enhanced in crops for making them nutritionally rich, and also for improving productivity. Preference needs to be given in developing transgenic crops that are antibiotic marker-free and safe from environmental security point of view for easy acceptability by the masses.

Genetic improvement of livestock is essential to meet the ever-increasing demand for milk, meat, wool and animal produce based drugs. In addition, the application of genetically modified animals through site-specific targeting will be of immense value for xenotransplantation and meeting the demand of biomedicine and organ replacement. In animals, genetic modification of host-derived embryonic stem cells has opened new vistas in gene and cell based therapy. This has been possible because of the availability of stable stem cell lines derived from pre-implantation embryos. Derivation of embryonic stem cells in farm animals can help in introducing precise genetic modifications into the genome of livestock species *via* gene targeting and in cloning larger number of animals from founder embryos.

The role of fish stem cells and their potentials in basic and applied research is well known. Embryonic stem (ES) cells are derived from early embryo. Its application in early embryonic development, regulation of gene expression, biological function of desired gene, producing valuable proteins for pharmaceutical purposes, providing animal models for biomedical research and above all, in producing and improving brood stock in aquaculture is promising. Harvesting and maintaining a line of stem cells from fish is still at an early stage. The success in stem cell line will have wide-ranging application both as an animal research tool and as a transgenic vehicle in improvement program for aquaculture. In fishes, primordial germ cells (PGCs) have been considered cells of high importance. However, assay for their precise identification has remained a challenge. Transplanted PGCs in fishes have been shown to be capable of developing into germinal tissue. This opens up a promising way, to develop modified organisms through developing germ line chimeras. In fishes, genetic modifications have been done for commercially important traits of which most important is growth. Considerable emphasis is given on the production of auto transgenic fishes.

ii. Rationale

With the advent of genetic engineering and biotechnological tools, transferring novel genes of economic value from one organism to another has become a reality. Transgenic crop plants with improved traits have been developed and commercialized in 17 countries, including USA and India. Major emphasis has been thus far on transgenics for resistance to insect-pests. However, attention needs to be focused on developing transgenic crops to increase the efficiency of micronutrient uptake and utilization, and to incorporate resistance to a range of abiotic stresses like drought and salinity. Recently, an alternative tool of plant genetic engineering, that is, plastid transformation has been developed, and shown to score over nuclear transgenic technology in terms of prevention of gene flow from transgenics to weedy and wild relatives. This technology needs to be translated to crop plants of economic importance.

Stem cell research is a "cutting edge" area of scientific research. Early embryos, possess a uniform population of pluripotent stem cells that can differentiate into all cell types of foetal and adult tissues. These embryonic stem (ES) cells can be isolated from the cluster of undifferentiated cells in inner cell mass of the blastocysts, which could be isolated, characterized and cultured as ES cell lines. These ES cells are essential for homologous recombination to achieve site targeted gene integration. Biotechnological applications to aquaculture are essential for enhancing production levels. The improvement is also required for value addition. Many of these techniques will need gene level manipulation. The stem cell lines can provide useful tools in such work.

iii. Conceptual framework

There is need to prioritize and focus on crop improvement using the transgenic technology to increase productivity, to maximize the efficiency of limited resources like water and nutrients, and thus to achieve food and nutritional security of the nation. Certain traits are difficult to be incorporated through conventional breeding methods due to the non-availability of desired genes in the germplasm of a particular crop species. Since genes have been identified for traits such as insect-pest resistance, resistance to abiotic stresses, and efficient uptake and utilization of micronutrients, it is possible to incorporate these genes to improve crop plants. More novel genes need to be isolated from diverse germplasm available in both USA and India, and used in developing transgenic crop plants.

Genetic modification of host derived embryonic stem cells has opened new vistas in gene and cell based therapy. It has been widely accepted that homologous recombination and gene targeting success rate in ES cells is 1 event per 10^5 cells in comparison to 10^7 cells from somatic tissues. This is primarily because ES cells are easier to reprogram than somatic cells and prove extremely valuable for animal cloning. Development of stable ES cells in farm animals is still in infancy in US as well as in India. Therefore, it would be desirable to harness the biotechnological tools and resources available in US and India to develop infrastructure and capabilities in this promising area.

The embryonic stem cells have potential for use in wide ranging applications. Most of the research in fishes has been on transplantation of randomly selected embryonic cells into host embryos. However, all the cells do not have capacity to develop into germ line cells. Primordial germ cells give rise to gamete producing cells in fishes. Therefore, it is very important to have targeted identification, harvest and transplantation of primordial germ cells to give rise to gametes with modified genome from the recipient fish. Transgenic methodologies can provide targeted improvement in traits of economic value, beyond the levels achievable through conventional breeding. It also breaks the barriers that come due to breeding specificity between the different species of organisms. This will need characterization of appropriate genes, regulatory elements and development of constructs to introduce into the target fish.

a Transgenics in Crops

i. Objectives

- Development of transgenic rice, wheat, mustard, banana, papaya and cassava with improved traits as tabulated below
- Development of plastid transformation technology in Brassica for targeted gene integration

Table : List of crops and traits identified for developing transgenics

Crop	Trait
Rice, Wheat	Micronutrients uptake and utilization
Mustard	Resistance to aphids, tolerance to drought/salinity
Banana, Papaya, Cassava	Resistance to viruses

ii. Activities

- Development of gene constructs for crops and traits listed above
- Development of transgenic rice, wheat, mustard, banana, papaya and cassava with improved resistance to biotic and abiotic stresses
- Transgene expression and its association with trait of interest in the transformants
- Evaluation of the transgenic plants for biotic and abiotic stress resistance
- Development of plastid transformation technology in Indian mustard for targeted gene integration

iii. Institutional framework

(Rs. in millions)

Sub-program	Partners		Tentative Budget
	India	USA	
Development of transgenic crops	NRCPB, NRCB, TNAU, UAS (D), CCS-HAU, MAHYCO	Texas A&M, Texas Cornell University, Ithaca	50

iv. Expected output / deliverables

- Transgenic crops with enhanced micronutrient uptake, and resistant to biotic and abiotic stresses

- Transgenic mustard with minimal concern for environmental bio-safety

b. Development of Transgenics in Animals

b 1. Development of Embryonic Stem Cell Lines in animals

i. Objectives

- To develop technique of producing pluripotent stem cells in goat and buffalo.
- To produce banks of universally compatible stem cells.
- To develop genetic markers for characterization of ES cells.
- To study the basic processes of developmental biology.
- To create ‘designer cells’ for further research and other applications.

ii. Activities

- Generation of *in vivo* and IVF embryos of goat and buffalo as donor of blastomeres/inner cell mass.
- Culture of isolated blastomeres on different cell types as feeder layers to support the growth of colonies of embryonic stem cells.
- Identification of molecular markers for the characterization of ES cells and their stability in culture.
- Homologous recombination of genes in ES cells for gene targeting
- Manipulations of ES cells in culture for differentiating into designer tissues and organs for further applications

iii. Institutional framework

(Rs in millions)

Sub-program	Partners		Tentative Budget
	India	USA	60
Development of embryonic stem cell lines in animals	NDRI, TNVASU, GBPUAT, PAU Reliance Life Sciences, Mumbai	University of Georgia, University of Wisconsin, University of Connecticut University of California, Texas A & M University	

iv. Expected output/deliverables

- ES cell banks of universally compatible stem cells will be available for site-specific genetic modification.
- These cells would provide more stable genome for animal cloning for improving farm animal productivity.

- This would involve cloned sires of progeny-tested males used for transmission of their elite genetics.
- Establishment of ES cells could also be used to counter loss of biodiversity.

b 2. Development of embryonic stem cell technology in *Labeo rohita*, an Indian Major Carp

i. Objectives

- Establishment of an ES cell line and application in aquaculture.
- Cryopreservation of ES cells and PGCs.

ii. Activities

- Identification of primordial germ cells
- Development of ES cell lines
- Cryopreservation of ES cells

iii. Institutional framework

(Rs. millions)

Sub-program	Partners		Tentative Budget
	India	USA	
Embryonic stem cell in fishes	CIFA, KAU	Purdue University, California Institute of Technology, Smithsonian National Zoological Park	20

iv. Expected output/deliverables

- Availability of expertise in the country for developing and storage of ES cell lines would facilitate replicating the success with other prioritized fish species.
- The technology for stem cell lines and their long-term storage coupled with gene manipulation methods can provide means for producing genetically modified *L. rohita* on larger scale.
- Cryopreservation of the developed cell lines will also serve as the repository for future disaster management for elite and improved germplasm and as a reference material.
- This endeavor will be a useful ex situ conservation tool also.

b 3. Cloning and gene targeting strategies for transgenesis in farm animals

i. Objectives

- To optimise the technique of somatic cell nuclear transfer in farm animals

- To study the expression of developmental genes in cloned embryos and offspring
- To develop gene construct of therapeutic proteins
- To standardize the transfection of somatic cells with genes of therapeutic value.
- To evaluate traits of the transferred and expression genes in designer cell lines *in vitro*.

ii. Activities

- Development of competent donor cells for nuclear transfer in goats
- Somatic cell nuclear transfer technique for optimization of animal cloning
- Development of suitable gene constructs.
- *In vitro* gene transfection and establishment of transgenic clones of cells
- Development of transgenic SCNT cloned embryos.Comparative assessment of transgenic and non-transgenic counterparts.

iii. Institutional framework

(Rs in millions)

Sub-program	**Partners**		**Tentative Budget**
	India	**USA**	100
Cloning and gene targeting strategies for transgenesis in goat	NBAGR, NDRI, NII (D), Shanta Biotech, Hyderabad	University of Connecticut Texas A & M University Cornell university University of Wisconsin, Madison University of Georgia University of Virginia	

ii. Expected outcome/deliverables

- Creation of transgenic cell lines for *in vitro* and *in vivo* expression of proteins of economic value, such as blood clotting factor IX/VIII.
- Self-sufficiency on technological platform for multiplying the elite and rare germplasm by cloning. Inducible expression of transgenes in nuclear transfer embryos will be useful for production of novel proteins in transgenic animals in a more controlled manner.

b 4 Transgenic fish for enhancing growth and N-3 Fatty Acids in selected commercially important fish

i. Objectives

- Selection, cloning and characterization of target novel genes and strong promoters from potential fish species
- Construction and development of auto-transgenic fish

ii. Activities

- PCR amplification, cloning and sequencing of genes of interest (PUFA desaturase /elongase genes) and strong promoters (Beta actin promoter) from *Labeo rohita*
- Development of constructs for growth hormone gene *(L. calcarifer*)
- Transgenesis using different strategies of gene delivery systems in target fish (*Clarias batrachus*)
- Studies on gene integration and expression in target fish

iii. Institutional framework

(Rs. in millions)

Sub-program	Partners		**Tentative Budget**
	India	**USA**	
Transgenic fish	CIFE GBPUAT	University of Connecticut Auburn University	20

iv. Expected output/deliverables

- The auto-transgenic sea bass is likely to be fast growing with higher production potential.
- Higher PUFA contents in target fish will enhance nutritional value of the aquaculture produce.
- Information on gene and availability of construct can be used for transgenic purpose in other organisms of interest.

C 4: Molecular approaches for plant and animal health protection

i. Background

With the intensification of the crop, livestock, poultry and fish production, import of germplasm, unrestricted movement, and selection pressure on the pathogens have resulted in emergence of diseases and associated problems. This warrants improvement of the existing surveillance repertoire and development of more dependable prophylactics/immuno-biologicals employing biotechnological tools.

The quality seed production of GM crops poses many challenges. The deliberate or inadvertent mixing of GM seed with non-GM seed lots carries the risk of adversely affecting the quality of the seed and international seed trade. Hence the establishment of reliable, efficient and cost-effective techniques for detection, identification and quantification of GM in non-GM seed lots is a necessity. Transgenes can be detected by identifying either recombinant DNA or recombinant protein. For the detection at the nucleic acid level, PCR-based methods are mainly used, whereas for protein-based detection, immunoassays such as ELISA and lateral flow strips methods are predominantly used, which provide qualitative results within few minutes.

The low productivity of 400 million livestock population in India is primarily due to infectious and metabolic diseases, poor nutrition. Many diseases are endemic in the country. Ineffective or non-availability of sensitive diagnostics and vaccines are the major impediments in disease control and / or eradication. To tackle the disease problems, a multi-pronged approach such as employing advanced immunological and molecular interventions to develop newer generation diagnostics and vaccines on one hand and improving feed efficiency and producing disease-resistant/tolerant animals and poultry on the other hand seem to offer sustainable strategies. Timely diagnosis of disease and use of immuno-prophylaxis will help in increasing productivity of the animals.

In India, shrimp aquaculture is an important economic activity, which is affected by a number of viral epizootics such as white spot viral disease, monodon baculo viral disease, taura syndrome, yellow head disease, and a number of other viral diseases. White spot syndrome is the most devastating of all and has been responsible for loss of about more than rupees 300 crores annually in India since 1995. Due to its high virulent nature vertical transmission and wide host range, including most crustaceans, it is difficult to prevent and control the spread of the disease.

ii. Conceptual framework

The changing global climatic, demographic, ecological, socio-economic conditions and global tourism are mainly responsible for the changing epidemiology of infectious diseases. Therefore, the need for precise and early-to-use laboratory and field surveillance systems and diagnostics using the cutting-edge technologies and high throughput assays is greater today.

The conventional methods for surveillance/detection of pathogens of crops, livestock, poultry and fishes have some inherent problems of low sensitivity and specificity. Thus, there is a need for development of fool- proof immuno-prophylactics against many pathogens of importance in livestock and fishery production systems. Using biotechnology tools, molecular diagnostic tests and immuno-prophylaxis can be developed which have better sensitivity/specificity and protection. Development of molecular diagnostics for plant diseases and transgenes in GM crops is yet another area of importance as it is essential for GM producers to assure purity and segregation of products and to trace genetic modification in breeding, for ensuring compliance with legislation by National authorities. In India. The program also envisages identification of target genes essential for the white spot syndrome and monodon baculo-viral infections in shrimp using siRNA technology.

iii. Rationale

There is a need to upgrade infrastructure and expertise on detection of pests and transgenes in bulk consignments. The development and use of molecular diagnostic tools is a resource and expertise demanding exercise particularly in instances where the available scientific information is insufficient or diagnostic kits are not available. The trade in agricultural commodities including GM crops, which is now under the ambit of International Agreements of World Trade Organization (WTO), further highlights the importance of molecular diagnostics to remain competitive. Since the therapeutic option is not effective against this virus, the disease problem in farmed shrimp can be efficiently tackled, if modern biotechnological tools like RNA interference (RNAi) are used.

a .Development of molecular diagnostic tools for detecting pests in plants/ planting materials and transgenes in GMOs

i. Objectives

- Development of molecular techniques for detection of transgenes, viruses, bacteria and other pests and variability therein in economically important species and their bulk samples
- Development of methodology for testing transgenicity of unknown samples to check the adventitious presence of the transgenes.

ii. Activities

- Development of protein and nucleic acid based kits for detection of pests/ their variability
- To standardize the ELISA and PCR-based methodology for detecting pests in a bulk sample
- Development of protein and PCR-based diagnostic kits for detecting transgenes
- Development of diagnostic kits for detecting the presence of transgenecity in a sample not declared as transgenic by targeting all the known promoter and terminator sequences or their proteins
- Standardization of methodology for detecting transgenes/ transgenecity in a bulk sample

iii. Institutional framework and tentative budget

(Rs. in millions)

Sub-program	Partners		Tentative Budget
	India	**USA**	
Molecular diagnostic tools in plant health	NBPGR, IARI, CICR, UAS (D), CCS HAU	Cornell University, Washington State University, Pullman University of Florida, Gainesville, FL 32611-0620	45

iv. Expected output / deliverables

- Molecular detection techniques for plant pests and transgenes
- Ready to use kits for detection of plant pests and transgenes
- Protocols for detection of pests and transgenes in bulk samples
- Quality control program for detection of subliminal level of pests and inadventitious presence of transgenes in unknown samples

b. Molecular diagnostics and vaccines for animal diseases

i. Objectives

- Biotechnological tools based diagnostics and vaccines against important animal diseases

ii. Activities

- Biotechnological tool based diagnostics in animals for Avian Influenza (AI), Bluetongue (BT), Newcastle Disease (ND), Classical Swine Fever (CSF)
- Development of vaccines for AI, BT, ND, CSF and poultry coccidiosis

iii. Institutional framework

(Rs. in millions)

Sl. No.	Sub-program	Partner		Budget
		India	US	
1.	Biotechnological tool based diagnostics for animals diseases. (AI, BT, ND, CSF)	IVRI, TNVASU, NDDB, CCS HAU,	USDA & CDC	530
2.	Development of vaccines a) Avian Influenza	HSADL, CARI	Plum Island Animal Disease Centre	
	b) Bluetongue	IVRI, TNVASU, MAFSU, CCSHAU	Iowa State University	

	c) Newcastle Disease	TAVASU, IVRI, PAU, Intervet, Indovax	University of Maryland, Minnesota & Cornell Univ.	
	d) Classical Swine Fever	AAU (J), ICAR NEHR, Intervet Pune	Iowa State University,	
	e) Poultry coccidiosis	IVRI, VH Group, Pune, CARI, TNVASU	USDA, Maryland Univ.	

iv. Expected outcome / deliverables

- Development of methodology for detection of transgenes, viruses and bacteria in economically important species.
- Understanding the disease process, management and control of diseases using new generation diagnostics and immuno-prophylaxis would significantly reduce the economic losses due to infectious disease thus augmenting the productivity of livestock and poultry.
- Development of penside diagnostics and vaccines of commercial value

c. RNAi mediated viral gene silencing with special reference to white spot syndrome virus (wssv) and monodon baculo virus (mbv) in shrimp

i. Objectives

- To develop a therapeutic RNA product for silencing viral genes with respect to WSSV and MBV in shrimps.

ii. Activities

- Design of suitable therapeutic RNAs that can silence the expression of WSSV and MBV in shrimp.
- Construction of suitable transfection vector system to transfer the therapeutic RNAs in *Penaeus monodon.*
- Development of a model for gene silencing in shrimp virus through introduction of the RNAs.
- Development of a therapeutic RNA product.

iii. Institutional framework

(Rs. millions)

Sub-program	**Partners**		**Tentative Budget**
	India	**USA**	
RNAi mediated gene silencing in shrimps	CIBA NBFGR KVAFSU	University of South Carolina	20

iv. Expected Output/deliverables

- Production of therapeutic tools that can be commercialized for shrimp viral disease control.
- Production of viral-free shrimp brood stock for virus-free shrimp seed.
- The expertise developed will be used for developing therapeutic protocol against other viruses also.

C 5. Quality assurance, value addition and safety of food products

i. Background

In the wake of liberalized trade under WTO, the quality and safety standards of food products have become more stringent. Further, there has been increasing consciousness of consumers about what they eat. They are prepared to pay for high quality products at competitive rates. However, there are concerns about food borne diseases, residual levels of chemical contaminants and total microbial levels in raw and processed products.

The natural resources are under threat due to environmental degradation. One of the causes of degradation is pollutant. The pollutants not only directly affect adversely, but can bioaccumulate and biomagnify in the food chain. The environmental pollutants interact with the DNA of aquatic organisms leading to a variety of genetic effects like tumor production, mutagenesis, altered gene expression and eventual adverse effect on fish biodiversity. There is a need for research to study the impacts of the important pollutants at molecular level especially the expression of genes. Thus, bio-monitoring protocols for assessment of the environment quality are required to be developed.

ii. Rationale

The analytical technique presently available for the detection of food-borne hazards are time consuming and tedious. Many of these are not suitable for online process monitoring. Therefore, it is necessary that rapid methods are developed for detecting various food-borne hazards to ensure that the products are absolutely safe and are of high quality to meet the international standards. There is a necessity to assess the impact of stress and the potential of natural biota to adapt and survive in changing environments. The study will help in characterization of toxicological effect of important toxicants at gene expression level. Gene expression profiling further may reveal molecular mechanisms of action of the pollutants.

iii. Conceptual framework

Quality and safety aspects have great importance in view of WTO agreement. The rapid detection of food-borne hazards on one hand require sensitive molecular tools and reliable, easy-to-use immunological kits for detection of food-borne pathogens, and on the other, novel techniques like biosensors and bio-luminometry for several chemical and biological hazards. The application of qualitative detection and prediction software would be an added advantage in ensuring the quality and safety of complex foods manufactured using modern processing technologies. Attempts have been made at NDRI, Karnal, to establish the role of emerging pathogens and the related food safety issues. Some methods based on PCR have also been standardized at IVRI for the rapid detection of a few foods-borne pathogens. Emphasis has also been given on the rapid detection of chemical hazards, such as pesticides and antibiotic residues in food products. Attempts have also been made on developing quantitative microbiological models for quality and safety prediction of dairy products.

a. Quality assurance, value addition and safety of animal food products

i. Objective

- Development of rapid detection kits, instruments and software for quality assurance and safety.

ii. Activities

- Development of rapid detection (molecular and immunodiagnostic) for food pathogens
- Application of molecular tools and biosensors in rapid detection of contaminants and pollutants
- Application of bioluminescent markers for on line monitoring of biohazards
- Development of food safety networks and databases
- Development of predictive models for quality and safety
- Development of software tools for risk analysis

iii. Institutional framework

(Rs. in million)

Sl. No.	Sub-program	Partner		Tentative Budget
		India	US	
1.	Risk assessment and management	NDRI, IVRI, CIPHET, CFTRI, CCSHAU,	Minnesota, Wisconsin, Madison, Illinois, Washington, UC Davis, Nebraska, Lincoln Universities	60

2.	Development of kits and software for detection of pathogen and contaminants	PD-ADMAS, IASRI, IVRI, GBPUAT,	USDA & CDC	
3.	Value addition to process and product development	NDRI, CIAE, PAU,	USDA, Ohio State Univ. & Purdue Univ.	

iv. Expected Outcome/deliverables

- Rapid detection kits for food pathogens.
- Biosensors for rapid detection of chemical hazards.
- Software for safety prediction of food products.

b. Eco-toxicogenomics studies in aquatic organisms in response to common water pollutants

i. Objective

- Development of genotoxicant specific gene expression signatures in aquatic organisms on exposure to environmental pollutants.

ii. Activities

- Gene expression studies in normal and exposed cell types/ tissues
- Development of tissue specific cDNA library for selected genes
- Development of DNA microarray to assess aquatic exposure and effect.
- Development of transgenic fish with fluorescent gene for biomonitoring of pesticides

iii. Institutional framework

(Rs. in million)

Sub-program	**Partner**		**Tentative Budget**
	India	**US**	
Eco-toxicogenomics studies in aquatic organisms	CIFRI, NBFGR, CMFRI, Cochin WBUAFS, Kolkata	University of North Carolina Auburn University University of Minnesota	40

iv. Expected output/deliverables

- Capacity in microarray based gene expression analysis.
- Information to redefine the safe levels of important pollutants
- Insight into the mechanisms through which pollutants alter the gene functions.

Annexure C 1

TENTATIVE BUDGET SUMMARY

(Rs. in million)

Sl. No.	**Sub-program**	**Tentative Budget**
C 1	**Genomics in Crops, Animals and Fishes**	**900**
	a. Pigeonpea genomics b. Buffalo Genomics c Finfish Genomics	600 200 100
C 2	**Molecular Breeding in Crops and Animals**	**300**
	a. Molecular Breeding in Crops b. Molecular Breeding in Animals c. Genetic resistance of host against livestock diseases (FMD in cattle)	150 100 50
C 3	**Development of Transgenics in Crops, Animals and Fishes**	**250**
	a. Transgenics in Crops b. Development of Transgenics in Animals b1. Development of Embryonic Stem Cell Lines in animals b2. Development of Embryonic stem cell technology for use as transgenic vehicle in *Labeo rohita*, an Indian Major Carp b3.Cloning and gene targeting strategies for transgenesis in farm animals b4. Transgenic fish for enhancing growth and N-3 Fatty Acids in selected commercially important fish	50 60 20 100 20
C 4	**Molecular approaches for plant and animal health protection**	**595**
	a. Development of molecular diagnostic tools for detecting pests in plants/ planting materials and transgenes in GMOs b. Molecular diagnostics and vaccines for animal diseases such as Avian Influenza, Bluetongue, Newcastle Disease, classical Swine Fever and Poultry coocidiosis c. RNAi mediated viral gene silencing with special reference to white spot syndrome virus (wssv) and monodon baculo virus (mbv) in shrimp	45 530 20
C 5	**Quality assurance, value addition and safety of food products**	**100**
	a. Quality assurance, value addition and safety of animal food products b. Eco-toxicogenomics studies in aquatic organisms in response to common water pollutants	60 40
	Total	**2145**

SECTION D: WATER MANAGEMENT

D 1. Background

Almost eighty per cent of the water is diverted to agriculture but because of poor management its use efficiency is low and varies between 35 to 40% at the field level. At the national level, the ground water contributes to about 50% in the irrigated areas and its intensive development has been one of the key-driving elements in ushering the green revolution but over exploitation of ground water has led to several other problems affecting the sustainability of the production base. It is anticipated that the total demand for fresh water in the year 2050 would be 1447 BCM as compared to 634 BCM in the year 2000. As a consequence of unplanned and rapid industrialization and urbanization the demand for sectors other than agriculture such as domestic, industrial and thermal power, is going to increase several times in the next few decades, as a result of which the share of water to agriculture will reduce by 10-15% in the next two decades. These competing sectors use water non-consumptively which implies that they use good quality fresh water and release poor quality and polluted waters into the natural system. Agriculture sector will, therefore, also have to depend more on utilization of these poor quality waters. It is probably the most appropriate time to think of these waste waters as a resource and plan for their use in a scientific, cost effective and eco-friendly manner.

Although India has an average annual rainfall of 117 cm, which is higher than the global average, most of it falls during the monsoon season as result of which more than 70 per cent is lost as runoff washing away a substantial amount of soil and nutrients. Considerable scope exists to harvest the large amount of unutilized rainfall. As a consequence of this erratic rainfall, India suffers from varying intensities of drought almost every year, a long term systematic strategy on water conservation is required to mitigate its impacts.

Irrigation commands are spread over large areas with very large spatial diversity of rainfall, soil and cropping pattern. Most of the watersheds are located in an inaccessible areas and it is difficult to physically monitor the impact of developmental activities. Use of modern tools like Remote Sensing, GIS and simulation techniques can be very effective in assessing and monitoring the water resources.

D 2. Rationale

The per capita water availability is declining continuously and likely to reach the stress and even scarcity levels in some regions in the next few years. There's, therefore, an urgent need to improve water use efficiency at all levels to meet the food, fibre and fuel requirement of 1.5 billion population in 2050. Injudicious and non-scientific abstraction of ground water has led to several problems like rapidly declining water table levels, salt upcoming, arsenic poisoning etc. It has also adversely affected the quality of ground water, deep aquifer exploitation and ingress of sea water into the fresh water zones. These are some of the key issues which need to be tackled judiciously in the immediate future.

Manual techniques for assessment and monitoring of water resources are time consuming, inefficient and costly. Tools like Remote Sensing and GIS can be effectively used for monitoring water use and productivity at fields, irrigation commands and watersheds. GIS and Remote sensing can also be used to develop Spatial Decision Support System for on Farm management and regulation of canal water supply. Fast growing use of internet has opened new avenue for development Web enabled data services and tools for disseminating information for management of water resources and can be very useful in developing real time irrigation management system. For efficient management of water resources there is need to develop spatial decision support system (SDSS), which integrate the spatial dimension and modeling capacity into an operational framework, so that DSS and GIS technology can both be more robust by their linkage and convolution.

One of the prime concerns is drought prediction and its early warning. This has to be followed with appropriate quantification of drought impacts. Management strategies are to be evolved to minimize the impact of drought. Identification of long-term drought-proofing strategies for minimizing production losses is equally important at the national level. Providing real time information to farming community needs further strengthening for effective management of drought situations.

D 3. Objectives

- To develop and demonstrate water management strategies for enhancing water use efficiency and productivity from field to system/sub basin level in irrigated and rainfed areas.
- To evolve technological and institutional interventions for augmentation and effective use and reuse/recycling of poor and marginal quality water.
- To integrate modern technology with incremental methods to assist in planning, management and dissemination of information for sustainable use of water resources with special emphasis on uncertainty and risk management.
- To evolve enabling processes for influencing national water management policies.

D 4. Conceptual Framework

This project will involve carrying out investigations at the field level at representative sites in the various irrigation commands and watersheds for a detailed analysis and monitoring of parameters essential to characterize physical, chemical, hydrological and associated parameters. Data gaps in information would be plugged in through intensive measurements and monitoring at various scales. State of art techniques will be used for data collection, storage and analysis including remote sensing, GIS. Long term impact studies will be done through field-based experiments and simulation models. Optimization models for water allocations among different users/sectors would be integrated into the DSS. The Web-Integrated Information System (WIIS) will contain general modules such as viewers, GIS, grid generators, a data warehouse and simulators, and domain-specific modules that will include all the relevant modules for tackling numerical modelling for the water-related physical applications under study, i.e. hydrology, hydraulics, hydrodynamics and floods.

The climatic factors that influence the interventions in drought management as well as proposed land use in watershed management programmes are mainly precipitation and temperature. The mission is to ensure the sustainability of agricultural industries and rural communities, through innovative scientific research focused on judicious rain water and ground water management and integrated crop /livestock systems including fisheries, considering socio-economic impacts and an assessment of all available water resources, providing scientifically sound information for public policy decision in a watershed mode. The methodology consists of identification of hot spots of drought occurrence in various agro-eco regions and development of strategies to mitigate drought on long-term basis, as well as provide information to the unreachable on real time basis.

D 5. Activities (Details in Annexure I)

i. Sustainable use of Ground Water Resources

Almost 50 % of the irrigated area is through ground water but its unscientific exploitation is creating problems and leading to many areas in the country being classified as dark and grey blocks. India has a coast line exceeding 8000 Kms and the coastal zone is highly productive but increasing exploitation and reduction of coastal fresh water out flows upsets the dynamic equilibrium in the coastal aquifers leading to saline water intrusion caused by mismanagement of aquifers. The saline water intrusion carries with it the risks of the matrix of the aquifers getting contaminated, causing a permanent loss to the fresh water storage capacity. In the islands ground water system is constituted by an unconfined aquifer in which relatively thin lens of fresh ground water floats over the saline water. The thickness of this lens gradually reduces from the centre of the island towards the sea. The dynamics of the fresh/saline water interface is governed by the abstraction of ground water on the island.

The studies in alluvial parts of Haryana, Gujarat, Punjab and U.P. have revealed the existence of a huge reserve of groundwater in the deeper aquifers which has not been fully utilized. The thickness of the alluvium in the area exceeds 500 m and only a small fraction of this is under active circulation due to prevailing shallow groundwater development. The under utilization of the groundwater from deeper aquifers has resulted in near stagnant conditions at depth and provided the necessary time factor for the deterioration in quality of ground water. Hence, while planning for ground water development in these aquifers, it is necessary to decide the volume of ground water to be extracted and the design of the abstraction structures.

The following activities will be undertaken in this project.

- Coastal aquifer management – creation of sub surface fresh water barrier for arresting salinity ingress
- Conservation and augmentation of ground water resources in small islands
- Deep aquifers – determination of safe yield and use of radio isotope techniques for determination of age and rate of flow of ground water
- Management of Aquifer recharge in water deficit areas

ii. Water quality management and remediation

Shallow groundwater constitutes a major source of groundwater supply for drinking as well as irrigation, particularly in alluvial aquifers which constitute a major area in northern India and upper aquifer of multi-aquifer systems in southern India. However, there has been an increasing concern regarding degradation of groundwater quality of shallow aquifers from various anthropogenic sources and activities, man induced intervention and natural disturbances in many parts of Indian subcontinent. Arsenic contamination in West Bengal Delta, fluoride contamination in Rajasthan, Gujarat and Andhra Pradesh are some of the notable examples. Landfills, waste disposals and drains containing waste water or polluted water are also polluting shallow groundwater in many urban areas. The unplanned and inappropriate exploitation of shallow groundwater resources and interaction of aquifers with polluted rivers/streams are further accentuating and complicating shallow groundwater quality problems.

The surface and groundwater resources are also under threat of contamination due to point and non-point sources of pollutants from industries, agricultural sector, municipal solid waste landfills and disposal of large volumes of domestic wastewaters into river and subsurface systems.

Considering the increasing demand of water by other sectors vis-à-vis agriculture, efforts are needed for safe use and recycling of these waste waters as they can be utilized with primary treatment. It is especially warranted in arid and semi-arid regions where water is scarce. Multiple uses of water both for enhancing water productivity as well as increasing livelihood options through alternatives like aquaculture need to be looked into. The following activities will be undertaken in this project.

- Shallow aquifer remediation
- Point and non-point source pollution
- Recycling and re-use of waste waters

- Productive use of marginal and poor quality waters including aquaculture

iii. Use of Modern tools in water management

In spite of massive investment in the irrigation sector in India, water availability at the field level and poor overall irrigation efficiency is a major concern. One of the reasons is that management of water resources is highly complex and tedious task that involves multidisciplinary domain including data acquisition and treatment, multi-processes and therefore multi-models, numerical modeling, optimization, data warehousing, and the analysis of exploitation, socioeconomic, environmental and legal issues.

Manual techniques for assessment and monitoring of water resources are time consuming, inefficient and costly. Tools like Remote Sensing and GIS can be used for monitoring irrigation water use and productivity at field and command level. Advances in remote sensing, GIS and modelling offer water resource researchers and managers an effective and reliable set of tools/techniques for obtaining accurate spatial data on actual water use, water demand, allocation and distribution of water, and crop yield.

Commonly used surface irrigation methods in India have very low efficiency of less than 40 % resulting not only in loss of precious water but also loss of energy. Realization of this has led to development of modern pressurized irrigation technologies such as LEPA (Low Energy Precision Application), LESA (Low Elevation Spray Application), MESA (Medium Elevation Spray Application) based on centre pivot or linear moved irrigation systems and micro irrigation systems (surface and sub-surface). In order to improve overall efficiency of these systems, research on automation techniques and irrigation and fertigation scheduling approaches based on ET networking station concepts needs to be carried out in India. Following activities have been planned in this project.

- Integrating space and information technology with water management for planning and decision making
- Decision support systems for management of uncertainty and risk in irrigated commands and rainfed agriculture
- Cost effective water and energy efficient irrigation systems and automation

iv Assessment and management of agricultural drought

Drought is a recurring phenomenon which cripples the economy of arid and semi arid regions significantly. Farmers in most of the agro-ecological regions are caught up in the nexus of poverty-drought-land degradation-natural calamity. Even in the better endowed humid regions, periodic drought due to the uncertainty and variability in the rainfall distribution has an adverse impact on overall productivity. Thus, assessment and management of agricultural drought is of paramount importance in the attempts to consolidate the gains from agricultural production technologies and enhancing the livelihood options from the rainfed region where most of the farmers are resource poor, small and marginal.

One of the prime concerns is drought prediction and early warning. This has to be followed with appropriate quantification of drought impacts and water management strategies to be adopted to minimize its impact. Apart from this, long-term drought-proofing strategies need to be identified for minimizing production losses. Identification of hot spots of drought occurrence in various agro-eco regions and development of strategies to mitigate drought on long-term basis, and as well to provide information to the unreachable on real time basis for effective management of drought conditions. The following activities are planned to be undertaken in this project:

- Quantification of drought using spatially distributed models
- Early warning systems
- Impact of climate change on droughts and identification of hot spots
- Long term drought proofing strategies
- Integrated agro-advisory systems
- Cost effective agrochemicals for enhancing water use efficiency
- Improved conservation agricultural techniques

D 6. Budget estimates

(Rs millions)

Sr. No.	**Activities**	
1	Sustainable use of Ground Water Resources	70
2	Water quality management and remediation	60
3	Use of Modern tools in water management	30
4	Assessment and management of agricultural drought	95
Total		**255**

D 7. Base Line Information

Limited data is available in terms of occurrence and movement of ground water and water quality variation based on the survey, exploration and monitoring programmes being carried out in the country. Some efforts have been made on modeling of groundwater quality and quantity by various workers but coastal aquifer management has been largely ignored. Scientific management of waste waters including their reuse and recycling is still in its infancy in spite of the large volumes being discharged every day by the domestics and industrial sectors. Application of modern techniques for real time decision making in water resources management is still lacking.

D 8. Expected Outcome/Deliverables

- Improved technologies/ methodologies for water management in irrigated commands and rainfed areas.
- Guidelines for sustainable ground water abstraction rates and salvage strategies for the coastal aquifers
- Tools to quantify point and non-point pollution load and its remediation measures for addressing groundwater quality problems
- DSS /models for drought and groundwater quantity and quality management
- Efficient early warning systems for drought, guidelines and tool kits for information and knowledge management and dissemination.
- Efficient conservation practices and optimum farming system strategies including aquaculture, for different agro-ecological regions for improved water productivity and enhanced income and livelihood options
- Policy briefs for water users, managers and policy makers.

Annexure D.1

Activities	Partners	
	India	**USA**
Sustainable use of Ground Water Resources	CGWB, All WTCs, HAU, PAU, MPUAT, GBPUAT	USGS, IFPRI, University of Minnesota
Water quality management and remediation	IIT (D), IIT (K), CPCB, CGWB/SGWD, BCKVV, WTC, IARI, CCS HAU, PAU, CSSRI, CIFE, CIBA, CIFA, CIFRI	Univ. of Colorado, MIT USGS, Univ. of California, Univ. of Minnesota, Univ. of Arkansas, Univ. of New Hampshire
Use of Modern tools in water management	ICAR-RCER, All WTCs, IIT(K), CRIDA, CSWRCTI, MPKV, SKAUD,	USU, Logan, OSU, Ohio, Texas A & M, Texas, USWCL, Phoenix, CSU, Fort Collins
Assessment and management of agricultural drought	CRIDA, ICAR RCER, ANGARU, CCS HAU, PAU, IGKV, WTC's, RAU (B),	Univ. of Nebraska, Texas A&M, USDA, Univ. of Arizona, Purdue University, IFPRI

Annexure D.2

(Rs in millions)

Themes/Activities	Partners		Tentative budget
	India	USA	
Sustainable use of Ground Water Resources • Coastal aquifer management – creation of sub surface fresh water barrier for arresting salinity ingress • Conservation and augmentation of ground water resources in small islands • Deep aquifer – determination of safe yield and use of radio isotope techniques for determination of age and rate of flow of ground water • Management of Aquifer recharge in water deficit areas	CGWB, All WTCs, CGWB, All WTCs, CGWB, All WTCs, CGWB, All WTCs, CCS HAU, PAU, MPAUT, GBPUAT,	USGS International Food Policy Research Institute (IFPRI) University of Minnesota	20 20 20 10
Water quality management and remediation • Shallow aquifer remediation • Point and non-point source pollution • Recycling and re-use of waste waters • Productive use of marginal and poor quality waters including aquaculture	IIT (D), CPCB, CGWB/SGWD, IIT (D), IIT (K) CPCB, IARI, CCS HAU PAU, CSSRI IIT (D), IARI CCS HAU, PAU, BCKVV CSSRI IIT (D), IARI, CIFE, CIBA, CIFA, CIFRI,	Univ. of Colorado MIT, USGS, Univ. of Colorado, MIT USGS, Univ. of California, Univ. of Minnesota Univ. of Arkansas Univ. of California Univ. of Arkansas Univ. of New Hampshire Univ. of Minnesota	10 20 10 20

Use of Modern tools in water management • Integrating space and information technology with water management for planning and decision making • Decision support systems for management of uncertainty and risk in irrigated commands and rainfed agriculture • Cost effective water and energy efficient irrigation systems and automation	ICAR-RCER, All WTCs, IIT (K) ICARRCER, All WTCs, IIT (K), CRIDA, CSWRCTI ICAR-RCER, All WTCs, IIT (K), MPKV, NAU, Jain Irrigation ltd., Jalgaon	USU, Logan, Ohio State University, Ohio, Texas A & M University, Texas, USWCL, Phoenix, Colarado State University, Fort Collins	15 5 10
Assessment and management of agricultural drought • Quantification of drought using spatially distributed models • Early warning systems • Impact of climate change on droughts and identification of hot spots • Long term drought proofing strategies • Integrated agro-advisory systems • Cost effective agrochemicals for enhancing water use efficiency • Improved conservation agriculture techniques	CRIDA, IARI, IIT (M) CRIDA, IARI CRIDA, CAZRI CRIDA, CAZRI,IARI CRIDA, IGKV,IARI IARI, ICAR RCER, All WTCs, ANGARU, CCSHAU, PAU, IGKV, All WTCs, JNKVV	Univ. of Nebraska, Texas A&M, USDA USDA, Univ. of Arizona, Purdue University IFPRI	20 15 20 15 10 10 5
Total			**255**