Adaptation Options for Agriculture, Forestry and Fisheries.
A Report to the UNFCCC Secretariat
Financial and Technical Support Division

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1 Introduction

One approach for dealing with climate change is to adapt operations so that they produce successfully under altered climate. This report discusses investment costs for climate change adaptation employed to offset climate change effects in an agricultural, forest and fisheries (AFF) production context. This discussion summarizes driving factors that cause a need for adaptation, basic AFF adaptation responses available, and a rough estimate of the costs of AFF adaptation focusing on **the year 2030**. In that context, the AFF adaptation being implemented in 2030 is assumed to augment existing adaptive investment that is a long standing ongoing AFF process and fisheries for example increasing yields and adapting to pests, insects and diseases.

The report considers two development scenarios. According to Smith (2007) the first is a "Business-As-Usual" (BAU) scenario and is based on the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emissions Scenarios (SRES) A1-B scenario (Nakicenovic and Swart, 2000). Smith states "This scenario assumes a population of about 8 billion by 2030 (about 2 billion more people than now). Average global per capita income is projected to rise from approximately $5,000 in 1990 to about $15,000 in 2030 (in 2000USD)." The second scenario is a "Mitigation" scenario based on the IPCC SRES B1 scenario. That scenario has the same projected increase in population as the base one, but per capita income is lower being about $12,000.

The other important aspect of the scenarios is the level of climate change. Smith (2007) states the 2030 "CO_2 concentrations and projected changes in temperature between the two scenarios [are] virtually indistinguishable (Houghton et al., 2001). By 2050, the CO_2 concentrations are almost 540 parts per million (ppm) in the BAU scenario and about 490 ppm in the Mitigation scenario. The global mean temperature increase differs only slightly between the two scenarios, about 1.6°C for the BAU scenario and 1.4°C for the Mitigation scenario".

1.1 Adaptation in an agricultural, fisheries and forestry context

Environmental and social adaptation is a fundamental and ongoing AFF sector activity. Production is highly dependent upon climate and other environmental forces along with societal evolution. Such forces vary substantially over time both in terms of long term trend and shorter run inter annual variability. This environmental/social evolution dependence leads to large variations in year-to-year production conditions and mandates adaptation. For example

- Crop production varies substantially from year to year with US total corn production varying by 20 to 30 percent with variations required in fertilization, pest control, irrigation and other management practices.
- Beef production practices vary substantially from year to year with locally adequate sources of feed in some years and the need for large quantities of imported feed in others with consequent management alterations in diet composition and animal selling practices and/or regional migration.
- Aquaculture production faces varying incidence of disease from year to year with alterations in disease control practices and other factors.
- Forests are at much greater risk of fire in some years than others with adjustments possible through management and prevention practices.

As inherent in the above examples, these sectors management regularly adapt to

- Long run forces such as development of pest resistance to treatment methods; development of irrigation facilities; invasive species; consumer diet preferences; income effects on dietary choices; competition for water from municipal and industrial forces, and changes in government policies among numerous other forces.
- Short run forces such as pest and disease outbreaks, El Niño Southern oscillation events, drought cycles, and extreme event cycles among numerous other forces.

Adaptation is generally in the form of

- Shifts in management practices (e.g. earlier planting dates or more heat tolerant livestock),
- Changes in enterprises employed at a particular site (e.g. adoption of more heat tolerant crops) or
- Adoption of new technology involving direct capital investment and or practice improvements developed by AFF practice research (addressing plant/animal species or varieties, genetic improvements, water retaining or application efficiency enhancing practices, improved tillage, better methods of fertilization, pest management competitor practices etc.).

In the AFF sector three principal institutions/forces support such adaptation.

- Research organizations that pursue the development of improved AF production practices and includes in country governmental research organizations, universities, international research organizations such as the Consultative Group on International Agricultural Research (CGIAR), and private companies such as those who develop pest treatment approaches, seed varieties, and livestock/fish species among others.
- Extension/training/outreach organizations that will pursue AFF practice training and diffusion largely encompassing country level extension personnel, company marketing and localized training organizations.
- The informal network of producers who share information and or observe and adopt practices of others.

One additional point relative to the AFF sectors and climate change is that AFF production is already heavily adapted to climate conditions. Production occurs across the landscape with highly productive systems occurring in areas with temperature and rainfall conditions much different than those projected under climate change. Thus, for example, conditions between the highly productive US regions in the irrigated areas of the High Plains of Texas and the dryland areas in the Midwestern Corn Belt are much more different than the 1.4-1.6 degrees Celsius that is projected to be the consequence by 2030 under the scenarios used herein. These productive areas are supported by substantial localized research and technology diffusion efforts plus investment in appropriate technology.

The main point of this is to argue that AFF can adapt globally to climate change and that adaptation will occur through

- Investment in direct physical production facilities
- Research investments anticipatory of societal and environmental changes a
- Extension activities that in turn facilitate adjustment at the producer level.

However regionally some areas may not have adaptive capacity and may end up with a much smaller level of AFF production and the need for AFF product imports and/or population out migration.

1.2 Methodology overview

This report estimates adaptation costs based on expansions needed in research, extension and physical capital expenditures both in terms of climate change and in terms of future evolutions in population and hunger under the scenarios with the latter being much larger than the former. In doing this, data on investments with respect to current Official Development Assistance (ODA), capital formation, research, and extension expenditures are drawn together. Subsequently attention is turned to future needs with projections done on research, extension and capital formation expansion based on past trends and the literature. This is all done under a business as usual scenario assuming no climate change. Subsequently, subjective measures are applied to the need for additional efforts under climate change with a 10% increase assumed in research and extension funding, plus a 2% increase in capital formation. In turn, under the mitigation scenario these percentages are reduced by 1.4/1.6 (the ratio of temperature increase between the climate change and the mitigated scenarios) .

1.3 Limitations in Estimating Adaptation Costs

There are many difficulties and limitations in estimating the costs of adapting to these scenarios as well as the ability to finance adaptation investments. Following Smith (2007) these include

- Adaptive capacity - Smit et al. (2001) identified six determinants that will influence the degree of adaptive capacity: Economic resources; Technology; Information and skills; Infrastructure; Institutions; and Equity. There are vast differences around the world in the availability of these factors with for example in the agricultural arena vast differences in investment rates in agricultural technology research and diffusion investment despite a large need in terms of fundamental food supply (see the arguments in Rosebloom (2004), Pardey, Alston, and Piggott (2006), and Pardey, Beintema, Dehmer, and Wood (2006))
- Adaptations are typically not to climate change alone. Most adaptations to the future will not be made solely because of climate change and unraveling the climate change component is virtually impossible. This led to arbitrary but somewhat informed assumptions herein.
- Costing method – the method whereby current global expenditures on research, extension and infrastructure investments with application of a rule of thumb is imperfect at best with a key uncertainty about additional costs which is an educated guess and may not be fully reflective of adaptation needs.

In addition the adaptation costs are of two fundamental forms – adaptation to population and income growth and adaptation to climate change. Thus two sets of assumptions were required and the population based adaptations were much larger and much more debatable. On the other hand conservative rates of growth were used in research and the assumptions of others like Rosebloom for developing country research investments and the Capital Formation database projection until 2030 for growth in capital needs.

Finally, while the report deals with the three sectors of agriculture, forestry and fisheries it is limited in it's inability to fully separate these sectors. For example, total research and extension expenditure data used in this study give expenditures across the aggregate of these sectors.

2 Investment levels in AFF efforts

Now let us draw together data on funding looking at overseas development assistance (ODA), gross capital formation, research funding to AFF activities and extension funding to AFF activities.

2.1 ODA funds

In this section, data are assembled giving estimates of investment and financial flows to address adaptation needs in AFF as gathered by the UNFCCC secretariat. These give Oversees Development Aid in 2000 and 2005 as the basis for estimates of future flows. The ODA consists of multilateral aid (e.g., from the World Bank) and bilateral aid (from individual nations). These funds are broken out in total by aid source and with the research/extension components broken out.

2.1.1 All AFF ODA funds

Table 1 presents multilateral and bilateral ODA by Agricultural, Forestry and Fisheries Sector in 2000 and 2005 (both are in millions of 2000USD).

Table 1. Multilateral and bilateral aid to Agriculture, Forestry and Fisheries in 2000 and 2005 (millions 2000USD)

	Bilateral	Multilateral	Total	Bilateral	Multilateral	Total
	2000	2000	2000	2005	2005	2005
Agriculture	$1,414	$3,362	$4,776	$2,091	$2,751	$4,842
Forestry	$292	$66	$358	$440	$125	$565
Fisheries	$161	$20	$181	$183	$141	$324
Total	$1,866	$3,448	$5,314	$2,714	$3,016	$5,731

All data on ODA in this report are from the Organisation for Economic Co-operation and Development (OECD) DAC database (OECD, 2007).

Table 2 presents ODA to these sectors by region in 2000 and 2005 (both in millions of 2000USD).

Table 2. Multilateral and bilateral aid to Agriculture, Forestry and Fisheries by region in 2000 and 2005 (millions 2000USD)

Region	Bilateral 2000	Multilateral 2000	Total 2000	Bilateral 2005	Multilateral 2005	Total 2005
South Asia	$59	$797	$1,103	$1,192	$1,607	$2,798
Southwest Asia	$0	$0	$0	$82	$51	$133
Southeast Asia	$6	$43	$48	$246	$386	$632
Central Asia	$0	$0	$0	$8	$54	$62
East Asia	$17	$0	$17	$160	$285	$444
LAC	$108	$0	$108	$315	$1,549	$1,864
North America	$0	$0	$0	$0	$0	$0
Pacific	$4	$0	$4	$20	$45	$65
Europe	$0	$0	$0	$52	$0	$52
Africa	$42	$5	$47	$772	$651	$1,423
Others	$0	$0	$0	$0	$0	$0
Total	$236	$161	$397	$1,866	$3,448	$5,314

Table 3 presents ODA broken out by sub sector by region in 2000 and 2005 (both in millions of 2000USD).

Table 3. Regional aid to Agriculture, Forestry and Fisheries sub sectors in 2000 and 2005 (millions 2000USD)

	Agric. 2000	Forest 2000	Fish. 2000	Total 2000	Agric. 2005	Forest 2005	Fish 2005	Total 2005
South Asia	$529	$76	$33	$638	$1,378	$235	$33	$1,646
Southwest Asia	$127	$0	$6	$133	$168	$1	$0	$169
Southeast Asia	$566	$57	$9	$632	$455	$27	$54	$536
Central Asia	$60	$2	$0	$62	$162	$31	$0	$193
East Asia	$422	$22	$0	$444	$453	$88	$0	$541
LAC	$1,767	$56	$41	$1,864	$752	$21	$31	$803
North America	$0	$0	$0	$0	$0	$0	$0	$0
Pacific	$45	$0	$20	$65	$3	$1	$43	$47
Europe	$49	$2	$1	$52	$86	$14	$0	$100
Africa	$1,212	$142	$69	$1,423	$1,384	$149	$163	$1,696
Others	$0	$0	$0	$0	$1	$0	$0	$1
Total	$4,776	$358	$181	$5,314	$4,842	$565	$324	$5,731

2.1.2 AFF ODA Funds with Extension Research Detail

Table 4 presents total ODA by Agricultural, Forestry and Fisheries Sector component in 2000 and 2005 (both are in millions of 2000USD) with breakdowns of components going to extension and research (where available).

Table 4. Multilateral and bilateral aid to Agriculture Forests and Fisheries in total and to research and extension in 2000 and 2005 (millions 2000USD)

	Research 2000	Extension 2000	Total 2000	Research 2005	Extension 2005	Total 2005
Agriculture	$40.4	$61.2	$4,775.7	$122.5	$101.2	$4,841.8
Forestry	$4.7	$4.2	$357.8	$0.9	$1.9	$564.6
Fisheries	$1.8	$10.6	$180.6	$5.5	$2.3	$324.4
Total	$46.9	$76.0	$5,314.1	$128.8	$105.4	$5,730.8

Table 5 presents total regional ODA with extension and research components broken out to total Agricultural, Forestry and Fisheries Sector activities in 2000 and 2005 (both are in millions of 2000USD).

Table 5. Regional ODA to Agricultural, Forestry and Fisheries Sector activities with extension and research components broken out in 2000 and 2005 (millions 2000USD)

	Research 2000	Extension 2000	Total 2000	Research 2005	Extension 2005	Total 2005
South Asia	$2.8	$15.5	$638.1	$6.4	$0.4	$1,645.7
Southwest Asia	$0.0	$1.9	$133.0	$0.2	$18.7	$168.7
Southeast Asia	$4.9	$22.7	$632.2	$9.2	$3.9	$535.8
Central Asia	$0.1	$1.0	$62.4	$0.3	$0.5	$192.6
East Asia	$4.2	$0.5	$444.3	$2.1	$0.1	$540.5
LAC	$8.0	$9.4	$1,864.3	$58.4	$39.7	$803.5
North America	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Pacific	$0.6	$0.1	$64.9	$0.3	$0.1	$47.4
Europe	$0.4	$0.2	$51.8	$0.5	$2.1	$100.0
Africa	$26.0	$24.8	$1,423.0	$51.5	$39.7	$1,695.7
Others	$0.0	$0.0	$0.2	$0.0	$0.0	$0.8
Total	$46.9	$76.0	$5,314.1	$128.8	$105.4	$5,730.8

Note these ODA data do not fully cover expenditures to globally focused developing country research and extension agencies like the CGIAR as their report shows year 2000 funding of $350 million which exceeds the above research report by almost an order of magnitude.

2.2 Investments in gross fixed capital formation

Table 6 presents current and projected investments in gross fixed capital formation (GFCF) data provided by the UNFCCC secretariat added across the categories of Rice, OthCrops, Livestoc, Meat, OthFood, into agriculture Forestry, WoodProd, and Pulp and paper into Forestry and Fishing into Fishery.

Clearly, substantially more money is invested in GFCF than in ODA both because of larger investments in high income countries and the size of private investment in developing countries . For example, total 2005 GFCF in agriculture is about $310 billion with about $190 billion in high income and $120 billion in developing whereas ODA in agriculture is about $5 billion. GFCF in forestry and fisheries are, respectively, about $126 and $5 billion with respectively $46 billion and $6 billion being sent in developing countries, compared to about $350 and $180 million in ODA. The majority of this investment occurs in OECD countries. Total GFCF is projected to about double by 2030. This is also broken down by development status in last two rows.

Table 6. Regional Gross fixed capital formation in AFF sectors (millions 2000USD)

	Agric 2005	Forest 2005	Fish 2005	Total 2005	Agric 2030	Forest 2030	Fish 2030	Total 2030
South Asia	$17,045	$5,068	$1,193	$23,306	$44,097	$15,966	$1,839	$61,902
Southwest Asia	$4,475	$1,097	$347	$5,919	$13,780	$12,148	$672	$26,601
Southeast Asia	$3,507	$3,773	$419	$7,698	$8,739	$10,081	$721	$19,542
Central Asia	$4,370	$475	$153	$4,998	$12,485	$1,820	$229	$14,534
East Asia	$64,123	$42,393	$3,987	$110,503	$132,512	$108,424	$5,566	$246,502
LAC	$38,406	$9,478	$788	$48,672	$76,875	$26,439	$1,186	$104,500
North America	$79,687	$64,787	$460	$144,934	$127,231	$92,663	$650	$220,544
Pacific	$6,202	$2,844	$68	$9,114	$10,904	$4,461	$93	$15,458
Europe	$71,550	$37,364	$2,723	$111,637	$132,245	$71,040	$3,483	$206,768
Africa	$20,624	$5,880	$1,012	$27,516	$45,728	$19,926	$2,025	$67,679
Total	$309,989	$173,159	$11,150	$494,298	$604,598	$362,968	$16,463	$984,030
Developing	$120,230	$46,423	$6,043	$172,696	$270,778	$156,314	$10,042	$437,135
High Income	$189,759	$126,736	$5,107	$321,602	$333,820	$206,654	$6,421	$546,895

2.2.1 Financing of fixed capital formation

The increase in capital formation above also raises the issue of how it is financed. Table 7 shows the breakdown of resource inflows into the developing world that was developed by the FAO , Committee on World Food Security (1999). This table shows a large trend toward private sources of funds.

Table 7. Total Net Resource Flows from DAC Member Countries and Multilateral Agencies to Aid Recipients

	1990	1991	1992	1993	1994	1995	1996	1997
Net Resource Inflows (billion $)	$129.6	$136.2	$156.9	$162.3	$219.1	$263.2	$364.7	$324.5
Percent from Development finance	59%	62%	50%	51%	39%	34%	21%	24%
Percent bilateral	29%	30%	26%	24%	19%	15%	11%	10%
Percent multilateral	10%	12%	11%	10%	9%	7%	5%	5%
Percent from Private	34%	37%	49%	50%	58%	64%	77%	78%
Percent from Private Direct Investment	21%	17%	18%	24%	22%	20%	17%	33%

Source FAO , Committee on World Food Security (1999)

Table 8 shows a similar breakdown developed by Saigal(2001).

Table 8: Net long-term resource flows to developing countries, 1991-2000

	1991	1995	1996	1997	1998	1999	2000
Total Resource inflows ($billion)	123	261	311	343	335	265	296
Share from Official flows	50%	21%	10%	13%	16%	17%	13%
Sharefrom Private	50%	79%	90%	87%	84%	83%	87%
Share from Capital Makets	21%	38%	48%	37%	31%	13%	27%
Share from Foreign Direct Investment	29%	41%	42%	50%	53%	70%	60%

Source Saigal (2001).

Based on these data the FAO committee concluded "Most of the above-required investments will result from private initiative, and therefore depend decisively on a conducive climate at the international and international levels". pp7.

Saigal however indicated the proportion of sectorally allocable aid reaching agriculture, forestry and fisheries fell sharply from the mid-1970s to about 20.2 percent in 1987-89 and then to 12.5 percent in 1996-98

2.3 Expenditures on research

Table 9 presents a year 2000 accounting of expenditures on AFF research drawn from Pardey, Beintema, Dehmer, and Wood (2006) who based that data on Pardey, Dehmer, and El Feki (2006). The data show research expenditures are substantially larger that the ODA component with global totals being about $36 billion in these data as opposed to $128 million in the ODA data. These data include private firms, and in-country expenditures. The data show a significant dominance by high income countries as extensively discussed in the bibliography entries by Pardey and associates.

Table 9: AFF Research Expenditures with Public and private breakdown of (millions 2000USD) plus percentage shares

	Expenditures			Share	
	Public	Private	Total	Public	Private
Asia-Pacific	$7,523	$663	$8,186	91.9%	8.1%
Latin America and the Caribbean	$2,454	$124	$2,578	95.2%	4.8%
Middle East and North Africa	$1,382	$50	$1,432	96.5%	3.5%
Sub-Saharan Africa	$1,461	$26	$1,486	98.3%	1.7%
Developing-country subtotal	$12,819	$862	$13,682	93.7%	6.3%
High-income country subtotal	$10,191	$12,086	$22,277	45.7%	54.3%
Total	$23,010	$12,948	$35,958	64.0%	36.0%

Source: Pardey, Beintema, Dehmer, and Wood. (2006)

The public private share is also important. Table 9 also shows this breakdown by region. These data show a large private presence, but with a dramatic difference in private shares between developing and high income countries, where about 93 percent of the private R&D being performed in high income countries, where it was the largest source of funding (some 54 percent). In developing countries, only 6 percent is private and there are large disparities in the private share among regions.

Finally, the growth in private share is worth presenting (Table 10). These data are only for high income countries since that is where the private money is being spent. There the data show research is increasingly a private-sector pursuit with the private share growing from about 44 percent in 1981 to 54 percent in 2000.

Table 10. Private funding share of research expenditures over time

	1981	1991	2000
Australia	5.9%	22.0%	24.8%
Canada	17.3%	21.5%	34.0%
France	44.1%	52.0%	74.7%
Germany	56.2%	43.6%	53.6%
Japan	36.6%	48.4%	58.6%
United Kingdom	55.9%	66.8%	71.5%
United States	49.3%	51.0%	51.5%
The Netherlands	44.8%	56.1%	57.7%
OECD total (22)	43.6%	48.5%	54.3%

Source: Pardey, Beintema, Dehmer, and Wood. (2006)

The ODA data are also biased by the fact that a substantial amount of development assistance is not directly to developing countries but rather to the CGIAR international research system that is largely funded by developed countries. However the research benefits largely accrues to developing countries through research developments. The CGIAR 2001 annual financial report shows their funding to be $350 million with 12 percent ($42 million) being spent on forestry, and 4 percent on fisheries ($14 million).

2.4 Expenditures on extension

Table 11 presents a historic accounting of expenditures on AFF extension drawn from Rosebloom (2004) who based the data on Swanson, Farner and Bahal (1990); FAO (1991); and Alston and Pardey (1996). The data show extension expenditures are substantially larger than the ODA component with global totals being about $6 billion in these data as opposed to $100 million in the ODA data. These data include private firms, and in-country expenditures. The data show a degree of dominance by high income countries.

Table 11: Estimated global estimates during year 1988 agricultural extension staff and expenditures, (millions 2000USD)

Region	Estimated 1988 Expenditures
South Asia	--
Southwest Asia	--
Southeast Asia	--
Central Asia	--
East Asia	$979
LAC	$258
North America	$1,357
Pacific	--
Europe	--
Africa	$529
Others	--
Rest of Asia-Pacific	$1,544
Other developing countries	$380
Other high income countries	$1,378
Total	$6,426

Sources: Swanson, Farner, and Bahal (1990); FAO (1991); Alston and Pardey (1996); Rosebloom (2004)

Note: The expenditure data were constructed by Swanson *et al* by multiplying the number of extension staff by a regional average cost per extension staff member. Hence the reported expenditure figures are crude, indirect estimates. Rosebloom amended the data by reporting China separately with lower wage rates and derived the USA figure from Alston and Pardey (1996). These data were updated herein to 2000$ using the US implicit GNP deflator.

3 Climate change effects on agriculture, forestry, and fisheries

Climate change can influence AFF in a number of ways. One can roughly group the drivers into six categories.

- **Temperature** as it affects plants, animals, pests, and water supplies. For example, temperature alterations directly affect crop growth rates, livestock performance and appetite, pest incidence and water supplies in soil and reservoirs among other influences.
- **Precipitation** as it alters the water directly available to crops, the drought stress crops are placed under, the supply of forage for animals, animal production conditions, irrigation water supplies, aquaculture production conditions, and river flows supporting barge transport among other items.
- **Changes in atmospheric CO2** as it influences the growth of plants by altering the basic fuel for photosynthesis as well as the water that plants need as they grow along with the growth rates of weeds.
- **Extreme events** as they influence production conditions, destroy trees or crops, drown livestock, alter water supplies; influence waterborne transport and ports; and damage aquaculture facilities.

- **Sea level rise** as it influences the suitability of ports, waterborne transport, inundates producing lands and alters aquaculture production conditions.
- **Climate change motivated greenhouse gas net emissions reduction efforts** as they would influence the desirability of production processes and the costs of inputs plus add new opportunities.

Agricultural sensitivity to climate change has been reviewed in the IPCC documents. Briefly one can group the effects on agricultural production into seven major categories and a number of subcategories

- **Plants** -- Climate change alters
  - Crop and forage growth -- climatic change can diminish crop growth in some places but also can increase crop/forage growth in places where productivity is cold limited by extending the growing season or removing frost risk. Extreme events can also damage crops, trees or forage availability.
  - Crop and forage water needs -- higher temperatures can increase plant and tree respiration needs and raise water demand.
- **Soils and land supply**-- the vast majority of agricultural production is tightly tied to the soil as a source of nutrients, stored water, etc. Climate change can alter soil characteristics including
  - Soil fertility – increased temperature generally stimulates the rate of microbial decomposition in the soil which in turn diminishes organic matter content along with nutrient and moisture holding capacity.
  - Soil moisture supply -- temperature, precipitation and organic content affect soil moisture supply. Increases in temperature lead to diminished soil moisture supply and thus increased precipitation would need to occur in order to replace diminished moisture supplies.
  - Land loss and non-agricultural competition for land—sea level rise can inundate land and severe climate change can lead to serious degradation making land largely unsuitable for agricultural use. Climate change may also alter demand for land such as housing or actions to designate protected areas for species protection or migration.
- **Animals** -- land animals are affected by climatic forces in terms of their individual performance and through the carrying capacity of lands on which forages grow.
  - Performance -- hotter temperatures can lead to diminished appetite and diminished growth potential as well as a larger need for energy to be devoted to maintenance as opposed to growth.
  - Pasture/range carrying capacity -- hotter temperatures and less precipitation can diminish forage growth and cause animals to need to use larger amounts of land plus use energy to walk further in order to eat an equivalent amount of forage.
  - Feed supply—changing conditions for feed grains and hay production affects market price and availability and in turn the costs of livestock production. Possible disruptions in transportation as it affects delivery of livestock feeds can affect availability and price.

- **Fish**– Fish are sensitive to climate, weeds, and freshwater inflows
    - Aquaculture in coastal waters could benefit from warmer conditions, with increased growth rates and increase in the geographic range of the activity but this would also imply a need for greater food supplies.
    - Higher water temperatures and related physical changes could result in more intense and frequent disease outbreaks and algal blooms (Kent and Poppe, 1998).
    - Bacterial contamination of oysters and other shellfish may be more frequent as water temperatures rise.
    - Fish species may migrate causing fisherman to need to go farther from home ports to catch a particular species. This may expose them to increasing hazards from the more frequent intense storms and higher waves. Increased frequency of intense storms and the trend towards higher wave heights would also physically endanger aquaculture operations.
    - Reduced water supplies and increased water usage could diminish freshwater inflows and alter the suitability of bays and estuaries as habitat.
- **Irrigation Water Supply** -- irrigation water is a key input to many productive agricultural lands. Climate change can alter the amount of water available for irrigation by increasing losses from water bodies, reducing runoff or increasing nonagricultural competition.
    - Availability and Evaporation loss -- precipitation is ultimately the source of much of the irrigation water (not always so for groundwater). However, higher temperatures can lead to greater evaporation losses which diminishes water supply so climate has a major affect on irrigation water all water availability.
    - Run-off --irrigation waters drawn from surface and groundwater sources largely originating from rainfall which in turn is either used by native plants and trees, infiltrates and or runs off into water bodies. Changes in precipitation and climate regimes influence the composition of landscape vegetation which can alter runoff amounts and seasonal patterns.
    - Non-agricultural competition -- water is used by industries, households and cities for cooling, manufacturing, and landscape maintenance. Changing temperature and precipitation regimes can expand nonagricultural water demand which typically has a higher use value than agriculture and thus has the potential to diminish agricultural supplies.
- **Pests and fires** -- a number of environmental pest and fire related AFF relevant items are susceptible to climate change.
    - Pests -- Insects, weeds and diseases (more generally pests) are more prevalent in the lower latitude (tropical) regions. This greater pest incidence is due to climatic conditions such as the lack of a substantial freeze. Alterations in temperature and precipitation as well as CO_2 can lead to different growth potential and possibly increase the populations of pests - weeds, insects and tree/plant/animal diseases.

- Fires – warmer and potentially drier conditions under general climate change trends and extreme events can alter fire frequency damaging trees, forages and some crops.
- **Other** -- a number of environmental pest related AFF relevant items are susceptible to climate change which we group here in a final composite category.
  - Product markets -- while a particular region may be capable of adjusting to climatic change, agricultural prices are determined in a global market place. Climate induced alterations in production regimes can alter commodity market availability and in turn prices which will affect agricultural income in areas without great direst climate change sensitivity.
  - Insurance -- many AFF producers use insurance to help manage risk. Climate changes including alterations in the frequency of extreme events will alter insurance availability and costs.
  - Waterborne transport – substantial volumes of agricultural products flows from production to consumption via waterborne transportation. Major droughts or floods can be disruptive of such transport. Sea level rise can alter facilities usefulness or operation cost. As a consequence climate change vulnerability arises in terms of precipitation, extreme events, and sea level rise.
  - Port, aquaculture production, boat mooring, and fishery processing facilities-- extreme events, sea level rise and changes in water flow regimes can affect many seaside facilities.
  - Carbon emissions and sequestration – climate change can alter soil carbon content and carbon loss through fires plus indirectly emissions.
  - The incidence of people at risk of hunger and food insecurity and in turn migration and civil unrest may rise with direct and indirect effects.

3.1 Effects in context and projections

AFF produces across areas where the differences in climate is far greater than the scenario projections. For example, the projected temperature change is substantially less than the difference in temperature between Northern and Southern California and Northern and Southern Texas. Observation of today's AFF production shows that across areas with very different climate regimes there are areas with significant AFF production. The AFF production patterns across regions with differing climates are substantially different and this is the essence of adaptation. Thus, while climate differs across these areas to a degree greater than projected by the GCMs this does not render AFF production impossible.

Most evidence on AFF response to a variety of changes such as sudden increases in food, fish or wood demand, or unexpected weather shocks, suggests that AFF production is highly adaptable. With even just a few years to adjust, farmers in many cases have been observed to be able to change crop mixes and practices to accommodate these forces. Thus farmer adaptations are expected to mitigate many of the potentially negative effects of climate change. However, on a regional basis limited adaptation resources information or practices may temper adaptation.

Production in the most high latitude areas is limited by cold and the length of the growing season while lower latitude production is often limited by heat. Warming will hurt the heat limited lands but help the cold limited regions. Thus, particularly for large countries which straddle this wide range of climate conditions, negative effects in some regions are likely to be balanced by positive effects in other regions.

The effects of climate change on AFF differs across regions and over time. Crop yields are generally expected to decline in low latitudes with any increase in temperature. For the first several degrees of increase in global mean temperature over 1990, global agricultural production could increase, driven by the increased yields in mid- and high latitudes. But, this will happen while yields in low-latitude areas decrease; thus, the potential for malnutrition in low latitude developing countries may rise (e.g. see Butt et al or Tubiello and Fischer). Malnutrition is projected to decline as a result of development, but the declines could be partially offset by climate change. There are many important uncertainties. Changes in extreme events could disrupt agricultural production with even just a few degrees of warming. Adaptation will play a key role in determining vulnerability.

The IPCC projected that global forestry would be modestly affected by climate, but that regional impacts could be more substantial. Generally studies have found that production of forests would shift from low-latitude to high-latitude areas (e.g., Irland et al (2001) ; Sohngen *et al.* (2001) and Sohngen and Sedjo (2005)). There could be significant changes in distribution and productivity of fisheries, with fish species in many locations becoming extinct, but fish productivity increasing for some species in some locations. Higher temperatures could adversely affect aquaculture, as could increased extreme weather, presence of new diseases, and other factors.

4 Basic forms of Climate change adaptation

In the face of the above climate change drivers and AFF productivity affects there are a number of different types of mitigating actions that could be pursued. These mitigating actions can be undertaken by or facilitated by different parties and take on different forms the characteristics of which have implications for investment needs.

Actions to mitigate or facilitate mitigation of climate change can be undertaken by four different parties.

- AFF operators like farmers, foresters and fishers
- Industry actors like input suppliers, and processors.
- Public entities like the government, international research organizations, universities
- International donors

The section below will overview a number of actions which could be undertaken by each.

4.1 AFF Operators

The fundamental actors in terms of adapting AFF production are the persons producing AFF goods who manage the land, trees, boats, aquaculture facilities and capital resources with which AFF production occurs. These individuals can choose to make changes in their management regime and activity mix, adopting alternative practices or enterprises which through their use make adaptations to changing climatic conditions. Some of the fundamental forms of adaptation are

- **Crop, forage, and tree species/varieties --** one can choose in the face of climate change to adapt by altering the mix of crop, forage grasses or trees species employed for example growing crops, grasses or trees which are more heat tolerant. More generally this involves replacing some proportion of the crop, forage and tree species populating the land with alternative species that perform more suitably in the face of the altered climatic regime. Typically this involves adopting practices from areas that have historically exhibited comparable climates. Adaptation can also involve adoption of alternative varieties of the same crops or trees that are more suitable in the face of the altered climate due to for example lower water needs, increased resistance to pests and diseases etc.
- **Livestock and fish species/breeds --** one can choose in the face of climate change to adapt by altering the mix of livestock, aquaculture fish species or target fish species. More generally this involves replacing some proportion of current species or breeds raised with alternative species or breeds that perform more suitably in the face of the altered climatic regime or in a fisheries context seeking alternative species that have potentially migrated into the fishing grounds. In aquaculture and domestic animal raising this involves adopting livestock/fish species from areas that have historically exhibited comparable climates. Adaptation can also involve adoption of alternative varieties/breeds of the same livestock or fish that are more suitable in the face of the altered climate due to for example more tolerance to heat, or a resistance to newly prevalent pests and diseases etc.

- **Crop and tree management** -- one can also change the management of the items being grown. In the case of crops one can plant or harvest earlier so as to adjust to altered soil warm-up rates, soil moisture conditions, earlier maturity dates, altered water availability regimes. Trees and can be managed with increased inputs, altered rotation ages, thinning to mitigate fire risk, replanting, or altered pest management among other possibilities. Producers may also use seasonal climate forecasting to reduce production risk.
- **Livestock and aquaculture fish management** – one may alter the way livestock and fish are managed, altering aquaculture facility characteristics, changing stocking rates, altering degree of confinement, improving rangeland forages, providing shade/ water among many other possibilities.
- **Wild fish management** -- Natural fish populations are generally common property resources and this precludes most of the management adaptations possible for crop, livestock, aquaculture and forest AFF production. Adaptation options thus center on altering catch size, days of effort and location of effort including changing fishing grounds and possibly relocating fleets. However nearly three-quarters of world marine fish stocks are exploited at levels close to or above their productive capacity and thus reductions in the level of fishing are required in many cases (Bruinsma, 2003, Brander, 2005). This may hamper adaptation.
- **Moisture management/irrigation** -- climate change can increase crop water needs, decrease water availability, decrease soil moisture holding capacity and/or increased flooding/water logging. Adaptation may occur in the form of provision of irrigation water including investing in facilities, changing drainage management regimes, altering tillage practices to conserve water, altering time of planting/harvesting to better match water availability, changing species to more drought tolerant plants/trees etc.
- **Pest and disease management** – Climate change is likely to exacerbate pest, disease and weed management problems Adaptation can occur through wider use of integrated pest and pathogen management or preventative veterinary care, development and use of varieties and species resistant to pests and diseases, maintaining or improving quarantine capabilities, outbreak monitoring programs; prescribed burning and adjusting harvesting schedules.
- **Management of natural areas** – Some AFF production occurs relies on passively managed, natural ecosystems which may require more active management under climate change to migrate in new better adapted species or deal with climate change enhanced pest, disease or fire risks.
- **Fire management** – Forests, grasslands and to some extent crop lands are vulnerable to fire and climate change induced increases in fire risk. Such risks may stimulate adaptive actions like salvaging dead timber, landscape planning to minimize fire damage, and adjusting fire management systems.
- **Land use or enterprise choice change** -- climate change may alter the suitability of land or a region to such an extent that certain enterprises are no longer sustainable and that it may be desirable to adapt by changing the land use from crops to pasture or trees, trees to grazing land. On a fisheries side it may be desirable to abandon aquaculture or discontinue pursuing certain fish species

in some regions. In either case one would use the associated land, capital and labor resources in other productive enterprises within or outside of the AFF sectors.

Many of these adjustment possibilities would proceed without need for direct capital investment but many would require some mix of capital and research investments. Almost al would require information and technology dissemination.

4.2 Industry level Private adaptation

Adaptation need not only occur at the producer level but also can occur at the industry level by parties like the following

- **Input supply firms** – such firms could facilitate adaptation by developing new practices, capital equipment, crop, tree, livestock or fish varieties, pest treatment methods/chemicals, chemical additives etc. which would be made available to AFF producers.
- **Processing Firms** -- adaptation by such firms would involve altering processing equipment to conform with new product mixes or products of different qualities along with the potential migration of processing facilities to other regions to accommodate shifts in locus of production.
- **Market trading firms** -- firms could move commodities domestically or internationally to accommodate changes in locations of production, and suitability of transportation facilities.

Most of these adjustments would be undertaken by profit profit-seeking firms and would not require public investments other than possibly incubator investments or research investments coupled with appropriate technology licensing arrangements to allow firms to pursue various adaptation possibilities.

4.3 Public facilitation of private adaptation

Governments, international organizations, and NGOs have roles to play in adaptation. This is where a lot of the public oriented investment exposure would occur. The types of adaptation actions that can be pursued are

- **Research** -- public investment can be placed into research to provide adaptation strategies that could be adopted by the AFF producers as discussed under the individual producer section above. This investment would be in the form of finding of direct government research organizations, international research organizations such as the Consultative Group for International Research, universities or research oriented NGOs.
- **Extension and training** -- traditionally substantial funding has gone into rural training and extension programs. Funding would need to go into those programs to disseminate adaptation options by providing information and training on practices that could be adopted by AFF producers.
- **Transitional assistance**-- climate change may stimulate location changes and migration. There may be an investment role for support of such, creating job opportunities, supporting incomes, developing new infrastructure/institutions, relocating industry, providing temporary food aid, improving market functions and developing insurance.

- **Trade policy**-- governments may need to revise trade policies to adapt to new climate change conditions providing freer access to international markets to allow imports and exports to mitigate lost production and deal with surpluses.
- **Infrastructure development** -- public investment may be needed to adapt to climate change conditions including development of new transport and municipal infrastructure, development of new lands, protect or improvements of existing lands, construction of irrigation/water control structures, protection of coastal resources, and incubation of new industries among other possibilities.

5 A cautionary note

Before entering into a discussion on investment needs it is important to note that adaptation may not entirely succeed with a gap existing between the potential adaptations and the realized actions. Many arenas of AFF production receive minimal direct management particularly in terms of forests, production relying on natural ecosystems, wild fisheries, and extensive grazing. Many low income producers have little access to information and may not know about adaptive possibilities. Also in forestry there are long time lags between planting and harvesting trees due to time for tree growth and forestry rotation.

6 Adaptation value in AFF

AFF production adaptation can be quite valuable. Returns to research, much of which adapts to climatic conditions shows high rates of return have consistently generated returns in double digits (see the reviews in Huffman and Evenson, (1993, 2006) and Pardey, Alston, and Piggott (2006)) while extension returns have similarly been high (Birkhaeuser, Evenson, and Feder (1991); Evenson (1991)).

Authors have also found that adaptation in the face of climate change can considerably reduce the effects of climate change in cases switching yield and income effects from negative to positive plus greatly reducing the risk of hunger effects (e.g. see Butt, McCarl, and Kergna (2006); Butt et al (2005); Adams et al(1999), Fischer et al(2005) and Kaiser et al (1993)). The literature also shows adaptation to be quite common (see the reviews and evidence on Mendelsohn and Dinar (1999), Mendelsohn (2006) and Mendelsohn, and Seo (2007)).

7 Adaptation investment and financing needs

7.1 Under BAU scenario

There are strong arguments regarding funding needs for agriculture under Business as Usual Scenarios even under the assumption that no climate change occurs.

Rosebloom indicates that today in many developing countries agricultural production and productivity growth has not been large enough to eliminate hunger and extreme poverty. He states this problem can be tackled by pursuing a twin-track strategy: (1) A more equitable distribution of food and income; and (2) A higher volume of agricultural output produced in a more sustainable manner principally through research and extension investments.

Pardey et al back up the need for a funding increase stating that investment in agricultural research has high returns but that there is pervasive under funding of agricultural research. They indicate and argue that

- Research expenditure data show a select few developing countries reaching higher levels of investment but with a large number either stalling or slipping in investment levels.
- Achieving the rate of agricultural productivity gains necessary to feed the generally faster-than-average growing populations requires much more explicit attention to tapping and adapting technologies developed elsewhere (the spillover effect) and better targeting of those technologies to maximize local food-security and agricultural development impact.
- Shifting scientific orientation of high income country research, suggests that the technology spillover pathways of the past may not carry forward, even to the near future.

Rosebloom addresses how much more developing countries could invest in agricultural research and extension without overshooting their target. He then develops a minimum expenditure target for low-income and lower middle-income countries of 2% of agricultural GDP which would mean roughly a doubling of investment in public agricultural research and extension and would require (based on 1995-99 figures) an additional investment in the order of $6 billion 2000US$ annually. He then states that the international donor community, could provide an incentive for this by matching calling for a $6 billion increase in international ODA research and extension oriented funds.

On the high income country side, Alston and Pardey (2007) as reported in Farm foundation 2007 (based on emerging work by Alston, Andersen, James and Pardey, 2007) indicate that from 1950 through 1989, the US national rate of productivity growth averaged 2.01%, but that from 1990 to 2002, the agricultural productivity growth rate averaged 1.11% per annum. In the Farm Foundation article Alston and Pardey (2007) state 3 contributing factors

- a run of unfavorable weather which for our purposes we will call the initial onset of climate change and which according to phone conversations with the authors amounts to about 30% of the problem
- declining rate of growth in US public sector spending on agricultural research and development which will arbitrarily be called 35% of the problem which is due to of which about 3% percent more would be needed to reverse the loss of public share or to reverse the problem 1% more funding,
- a progressive redirection of agricultural research funds away from improving farm productivity to address such other concerns as environmental issues, human health and food safety which will arbitrarily be called 35% of the problem and which we will say amounts to a loss of 30% of the research funding or a need for another 1% of public funds.

In addition we note growth in research funds exists and we will assume it is about 2% per year which is lower than recent historic trends.

In turn assuming this is true across all high income countries we would need to take existing expenditures of about $35 billion and grow this at 2% a year until 2030 and assume during this growth that we would restore the productivity growth loss sans the climate effects then we allocate 46% of that to public and 54% to private. We assume the CGIAR funds are part of this investment. We also add in $6 billion in developing countries and $6 billion in matching donor aid from high income country sources in the form of ODA. In the developing countries we assume 97% of this is public.

In terms of extension, we will make the assumption that the current level of high income country spending is adequate and that the developing country expenditures need to go up by 20% (an arbitrary assumption) or about $550 million which we will assume is equally split between the developing countries public sector and the high income public sector (donors).

Finally we assume that the regional gross fixed capital formation forecast we were given in an UNFCCC database which shows the projected rise in capital stock by 2030. We assign 50% of the developing country part to their private sector being cognizant of the Saigal (2001) arguments about support to agriculture along with 40% to developed country private investment and 10% to public ODA increases in accordance with the strong trend toward private sector dominance of resource inflows. All of the high income country capital formation is assigned to their private sector.

Thus in total we get what is in table 12 which it a total investment increase of $520 billion to support 2 billion more people or $260 per person..

Table 12: Investment needs and funds sources under evolution to 2030 ***without consideration of climate change*** in millions 2000USD

	Scenarios Examined		**Needed Additional Investment**	**Allocation of Needed Investment**				
				Share in developing country		**Share in high income countries**		**Total financing burden**
	Current year 2000	**SRES no climate change**	**due to growth**	**Private**	**Public**	**Private**	**Public**	
Research in developing Countries	$13,682	$25,682	$12,000	$180	$5,820		$6,000	$12,000
Research in high income Countries	$22,277	$40,352	$18,075			$9,760	$8,314	$18,075
Extension in developing countries	$2,735	$3,282	$547	$0	$274		$274	$547
Extension in high income countries	$3,691	$3,691	$0			$0	$0	$0
Capital Formation in developing countries	$172,696	$437,135	$264,439	$132,220	$0	$118,998	$13,222	$264,439
Capital Formation in high income countries	$321,602	$546,895	$225,293			$225,293	$0	$225,293
Total Investment in developing countries	$189,113	$466,099	$276,986	$132,400	$6,094	$118,998	$19,495	$276,986
Total Investment in high income countries	$347,570	$590,938	$243,368			$235,053	$8,314	$243,368
Total	$536,683	$1,057,037	$520,354	$132,400	$6,094	$354,051	$27,810	$520,354

7.2 Results with BAU scenario incorporating climate change

The results above were highly dependent on the research expenditure real growth of 2% a year and the large assumed growth in capital formation as expenses to supply future AFF productivity needs. Now suppose we turn to the more narrow issue of how much investment would be needed to adapt to climate change and how could that be financed. This leads to much smaller numbers.

Agricultural research is frequently focused on climate issues. A number of recent efforts are motivated by climate change but traditionally the majority of the effort has been

- reflective of climatic challenges that pervade large areas in the developing world
- pursuing the goal of adapting highly productive crop, livestock, forest and fishery production systems into areas that have always been climate challenged.
- In my reading I come upon a statement somewhere that said 10-20% of the CGIAR system research was spent on climate adaptation on an ongoing basis. However this is at best an estimate. Private communications with CGIAR knowledgeable experts indicate that the 10-20% estimate is highly speculative. The CGIAR system does recognize climate change as an important research issue and is in the middle of a planning process directed toward a needed expansion in effort to address it.

Climate change will have three implications for agricultural research

- The pace at which adaptation research will be needed will increase as the focus of such work will be increasingly oriented toward maintaining productivity in places where productivity is being eroded by climate change.
- The above assumed 2% annual expansion in research needed to meet future food demands will expand the research pool and a significant amount of this expansion will likely address climate issues.
- Climate change will unless funds are expanded divert funds from other research pursuits and as such require some expansion in research funds to maintain total across the board effort.
- Research directed toward climate change will likely generate high rates of returns and non climate related spillovers (see the reviews in Huffman and Evenson, (1993, 2006) and Pardey, Alston, and Piggott (2006))

Based on this and the CG system estimates I will assume that more rapid climate change would increase the need for research and extension funding by 10% in total.

Capital expansion would also be affected. The business as usual scenario above showed a doubling in capital formation and since agricultural and fisheries capital tends to have a short life (10-20 years) most of that capital will be new by 2030 and as a consequence at least partially adapted to climate change. In addition, there will be new capital needed to for example irrigate areas or adopt new practices. I assume that capital formation would increase by 2% to accommodate these needs. This leads to Table 13 which indicates the need for $12.8 billion in investment.

Finally it is worthwhile in passing to mention why such an assumption laden process was used as opposed to relying on results of prior studies. There were three reasons for this

- The studies that have been done have generally examined what would happen if adaptation measures were put in place without ever questioning how to create and disseminate the adaptation measures. When new breeds or varieties or practices are developed research expenditures are needed for development and extension expenditures for dissemination.
- This project was done with a limited budget in a short time precluding for example development of a regional vulnerability map and then an assignment of research, extension and capital formation on that basis.
- The business of climate change adaptive research, extension and capital formation is just beginning and assignment of marginal costs of adaptation to given degrees of climate change is simply not approachable in a rigorous scientific manner at this point.

Table 13: Investment needs and funds sources under evolution to 2030 ***with consideration of alterations due to adaptation to climate change*** in millions 2000USD

	Scenarios Considered		Added Investment due to Climate Change	Allocation of Needed Investment				
				Share in developing country		Share in high income countries		Total financing burden
	SRES no climate change	SRES with climate change		Private	Public	Private	Public	
Research in developing Countries	$25,682	$26,882	$1,200	$18	$582	$0	$600	$1,200
Research in high income Countries	$40,352	$42,159	$1,807	$0	$0	$976	$831	$1,807
Extension in developing countries	$3,282	$3,337	$55	$0	$27	$0	$27	$55
Extension in high income countries	$3,691	$3,691	$0					$0
Capital Formation in developing countries	$437,135	$442,424	$5,289	$2,644	$0	$2,380	$264	$5,289
Capital Formation in high income countries	$546,895	$551,401	$4,506	$0	$0	$4,506	$0	$4,506
Total Investment in developing countries	$466,099	$471,967	$6,543	$2,662	$609	$2,380	$892	$6,543
Total Investment in high income countries	$590,938	$597,251	$6,313			$5,482	$831	$6,313
Total	$1,057,037	$1,069,219	$12,857	$2,662	$609	$7,862	$1,723	$12,857

7.3 Results with BAU scenario incorporating mitigated climate change

Finally we turn to mitigated climate change. Therein one should not expect much of an investment level change as research, extension and capital formation are needed to be expended to adapt under either case and the 2030 temperature difference between the scenarios is small. In this case expenditures were reduced to be 1.4/1.6 times the unmitigated scenario. This leads to the Table 14 which indicates the need for $11.3 billion in investment.

Table 14: Investment needs and funds sources under evolution to 2030 ***with consideration of adaptation to climate change and mitigation*** in millions 2000USD

	Scenarios Considered		Added Investment due to climate change and mitigation	Allocation of Needed Investment				
				Share in developing country		Share in high income countries		
	SRES with no climate change	SRES with climate change and mitigation		Private	Public	Private	Public	Total financing burden
Research in developing Countries	$25,682	$26,732	$1,050	$16	$509	$0	$525	$1,050
Research in high income Countries	$40,352	$41,933	$1,582	$0	$0	$854	$728	$1,582
Extension in developing countries	$3,282	$3,330	$48	$0	$24	$0	$24	$48
Extension in high income countries	$3,691	$3,691	$0					$0
Capital Formation in developing countries	$437,135	$441,763	$4,628	$2,314	$0	$2,082	$231	$4,628
Capital Formation in high income countries	$546,895	$550,838	$3,943	$0	$0	$3,943	$0	$3,943
Total Investment in developing countries	$466,099	$471,825	$5,726	$2,330	$533	$2,082	$780	$5,726
Total Investment in high income countries	$590,938	$596,462	$5,524			$4,797	$728	$5,524
Total	$1,057,037	$1,041,554	$11,250	$2,330	$533	$6,879	$1,508	$11,250

7.4 Summary with allocation to sectors

The above data can be allocated to the individual sectors under a number of assumptions. In particular the research and extension funding is assumed to be applicable to the sectors in the same proportions as the CGIAR system money is allocated with 84% going to agriculture, 12% to forestry and 4% to fisheries as in the 2001 annual report. Simultaneously capital formation is assumed to occur in the sectors in the same proportions as in the capital formation database. The shares therein differ between developing and high income countries. The resultant percentage shares are given in table 15.

Table 15 Shares of capital formation by AFF subsector

	Agriculture	Forest	Fisheries
Developing	69.6%	26.9%	3.5%
High Income	59.0%	39.4%	1.6%

In turn Table 16 gives the allocation by sector and country development/income class in the categories used above.

Tese data show the expected result that agriculture requires the largest proportion of investment followed by forestry and fisheries.

Table 16: Summary of financial needs by AFF sector

	Current Investment level	Added investment under BAU without climate change		Added investment above BAU due to climate change		Added investment above BAU due to mitigated climate change	
		$	% increase over current	$	% increase over current	$	% increase over current
Ag Research in developing Countries	$11,493	$10,080	88%	$1,008	8.8%	$882	7.7%
Ag Research in developed Countries	$18,713	$15,183	81%	$1,518	8.1%	$1,328	7.1%
Ag Extension in developing countries	$2,297	$459	20%	$46	2.0%	$40	1.7%
Ag Extension in developed countries	$3,100	$0	0%	$0	0.0%	$0	0.0%
Ag Capital Formation in developing countries	$120,230	$184,101	153%	$3,682	3.1%	$3,222	2.7%
Ag Capital Formation in high income countries	$189,759	$132,933	70%	$2,659	1.4%	$2,326	1.2%
Total ag investment in developing countries	$134,020	$194,640	145%	$4,736	3.5%	$4,144	3.1%
Total ag investment in high income countries	$211,572	$148,115	70%	$4,177	2.0%	$3,655	1.7%
Ag Total	$345,592	$342,756	99%	$8,913	2.6%	$7,799	2.3%
Forest Research in developing Countries	$1,642	$1,440	88%	$144	8.8%	$126	7.7%
Forest Research in developed Countries	$2,673	$2,169	81%	$217	8.1%	$190	7.1%
Forest Extension in developing countries	$328	$66	20%	$7	2.0%	$6	1.8%
Forest Extension in developed countries	$443	$0	0%	$0	0.0%	$0	0.0%
Forest Capital Formation in developing countries	$46,423	$71,085	153%	$1,422	3.1%	$1,244	2.7%
Forest Capital Formation in high income countries	$126,736	$88,783	70%	$1,776	1.4%	$1,554	1.2%
Total Forest investment in developing countries	$48,393	$72,590	150%	$1,572	3.2%	$1,376	2.8%
Total Forest investment in high income countries	$129,852	$90,952	70%	$1,993	1.5%	$1,743	1.3%
Forest Total	$178,245	$163,542	92%	$3,565	2.0%	$3,119	1.7%

Fisheries Research in developing Countries	$547	$480	88%	$48	8.8%	$42	7.7%
Fisheries Research in developed Countries	$891	$723	81%	$72	8.1%	$63	7.1%
Fisheries Extension in developing countries	$109	$22	20%	$2	2.0%	$2	1.8%
Fisheries Extension in developed countries	$148	$0	0%	$0	0.0%	$0	0.0%
Fisheries Capital Formation in developing countries	$6,043	$9,253	153%	$185	3.1%	$162	2.7%
Fisheries Capital Formation in high income countries	$5,107	$3,578	70%	$72	1.4%	$63	1.2%
Total Fisheries investment in developing countries	$6,700	$9,755	146%	$235	3.5%	$206	3.1%
Total Fisheries investment in high income countries	$6,146	$4,301	70%	$144	2.3%	$126	2.0%
Forest Total	$12,845	$14,056	109%	$379	3.0%	$332	2.6%
AFF Research in developing Countries	$13,682	$12,000	88%	$1,200	8.8%	$1,050	7.7%
AFF Research in developed Countries	$22,277	$18,075	81%	$1,807	8.1%	$1,582	7.1%
AFF Extension in developing countries	$2,735	$547	20%	$55	2.0%	$48	1.8%
AFF Extension in developed countries	$3,691	$0	0%	$0	0.0%	$0	0.0%
AFF Capital Formation in developing countries	$172,696	$264,439	153%	$5,289	3.1%	$4,628	2.7%
AFF Capital Formation in high income countries	$321,602	$225,293	70%	$4,506	1.4%	$3,943	1.2%
Total AFF investment in developing countries	$189,113	$276,986	146%	$6,393	3.4%	$5,726	3.0%
Total AFF investment in high income countries	$347,570	$243,368	70%	$6,313	1.8%	$5,524	1.6%
AFF Total	$536,683	$520,354	97%	$12,707	2.4%	$11,250	2.1%

8 Financing needs and sources

Summarizing the data above we have the financing needs in table 17 that show need for a global 49.2% increase in AFF related financing to match the without climate change baseline caused by 1/3rd more people. In turn sharing this out we find a need for a substantial increase in developing country private share (76%) largely due to the need for capital formation and a 38% increase in developing country public research and extension funding. In high income countries we find the need for a 106% increase in private funding largely for research and capital formation and an 199% increase in government research and extension funding. An accompanying 123% increase in ODA would also be required. This would also embody a 123% increase in ODA.

When we talk about adaptation to climate change the results show need for a global 1.2% increase in financing above the without climate change baseline($12.9 billion). In turn sharing this out we find a need for a 1.5% increase in developing country private share ($2.6 billion) largely due to the need for capital formation and a 3.8% increase in developing country public research and extension funding ($609 million). In high income countries we find the need for a 2.4% increase in private funding largely for research and capital formation ($7.8 billion) and an 12.4% increase in government research and extension funding (1.7 billion). This would also embody a 16.8% increase in ODA.

When we talk about adaptation to mitigated climate change the results show need for a global 1.1% increase in financing above the without climate change baseline caused solely by climate change or $11.3 billion 2000 USD. In turn sharing this out we find a need for a 1.3% increase in developing country private share ($2.3 billion) largely due to the need for capital formation and a 3.3% increase in developing country public research and extension funding ($533 million). In high income countries we find the need for a 2.1% increase in private funding largely for research and capital formation ($6.8 billion) and an 10.8% increase in government research and extension funding ($1.5 billion). This would also embody a 14.7% increase in ODA.

Table 17: Summary of financial needs by source and type of assumption plus added levels of ODA

	Total		In developing countries				In high income countries			
			Private		Public		Private		Public	
	Amount	%	Amount	%	Amount	%	Amount	%	Amount	%
Current level	$1,057,037		$173,106		$16,007		$333,632		$13,938	
Added Investment for BAU change	$520,354	49.2	$132,400	76.5	$6,094	38.1	$354,051	106.1	$27,810	199.5
Added investment for climate change	$12,857	1.2	$2,662	1.5	$609	3.8	$7,862	2.4	$1,723	12.4
Added invest. mitigated climate change	$11,250	1.1	$2,330	1.3	$533	3.3	$6,879	2.1	$1,508	10.8
Current Donor ODA	$5,314.0								$5,314	
ODA increase component BAU	$6,543	123.1							$6,543	123.1
Added ODA Climate change	$892	16.8							$892	16.8
Added ODA. mitigated clim ate change	$780	14.7							$780	14.7

Notes Amount is in million $2000USD

8.1 Sources of financing

The international donor funding is largely for research and extension and would arise through the CGIAR system, donor agencies and the World Bank.

The private sources of financing would come from multinational seed, chemical companies and other input companies plus domestic AFF producers and processing firms. Private funding could also come though emissions permits revenues.

The public funding would be diverted government revenues sent on research and extension plus perhaps some public works (all of these are assumed zero in the above analysis.

8.2 Will new mechanisms be needed

Current financing arrangements need to change in a couple of fundamental ways

- Research funding may need to find a new more accountable system that captures large potential gains in developing countries with a larger share than calculated here for private developing country investment. See arguments in Pardey, Beintema, Dehmer, and Wood (2006).
- Research funding may require a more production orientation with a decline in the relative share of funds devoted to environmental issues, human health and food safety,
- Private developing country funding depends in a key way on development and the allocation of a substantial amount of the development rewards to capital formation and to a lesser extent research.
- Private funding may somehow be linked to carbon emission funds as argued in the

9 Conclusions

Climate change will continue to affect agriculture forest and fisheries, necessitating mitigation of greenhouse gases and adaptation to avoid undesirable impacts. A range of adaptation actions have been identified, but the extent of these needed cannot be fully linked to climate change. Many adaptation actions, however, have commonly been used and involve research, extension and infrastructure investments. These estimates amount to

- US$520 billion or $260 per new person for a BAU scenario without climate change largely due to large efforts needed to deal with advances in population. this adds
- An added US$12.9 billion without mitigation when climate change is considered and
- An added US$ 11.3 billion when mitigated climate change is considered relative to the no climate change baseline.

This will cause need for a substantial increase in developing countries participation.

It is also worth mention that the magnitude of these investments is large compared to the value of climate impacts and may turn some of the positive with adaptation assumptions to negative after considering the cost of developing and adopting adaptation.

Finally the text above assumes the way to adapt is largely through research, capital and outreach investment. The outreach component is key here as the information on adaptive practices must filter out at the field and government level to AFF producers and such coordinated efforts to climate-proof development will not be cheap but actually face the same challenge as currently being encountered with efforts to increase productivity as a means to enhance incomes and reduce world hunger.

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