Climate Smart Agriculture (CSA)

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Climate Change refers to a change in the state of the climate that can be identified (e.g. by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. "Climate" is therefore different from "weather", with refers to short term events. Climate change may be due to natural internal processes or external influences (*forcings*) such as fluctuations of solar cycles, volcanic eruptions, and persistent changes in the composition of the atmosphere or in land use due to human activities (*anthropogenic*).

> The Framework Convention on Climate Change (UNFCCC) defines climate change as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.' The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes.

Long term changes in the World's climate are a reality, verified beyond reasonable doubt by numerous studies, and so have to be factored into the design of Concern's work in the field, particularly long term investments. Concern's definition of the extreme poor (How Concern Understands Extreme Poverty) means that many of those we work with are often those who are directly affected by changes in climate.

Vulnerability: The rural poor tend to live in areas that are already marginal for agriculture, so small changes in climate will generally result in significant reductions in crop yield, with some exceptions were yields are expected to increase. The cost of land means that both the urban and rural poor live in the cheapest areas, which are usually areas already prone to flooding, drought, soil erosion/degradation and landslides, risk that are expected to increase due to climate change. As the land is often rented, or the poor are technically squatter, there is little incentive to invest in long-term measures to reduce risk. As tenants or squatters the poor may not be eligible for government grants or services. The poor spend a greater proportion of their income on food, e.g. 78% in Malawi, and are therefore exposed to increases in food prices linked to climate change.

Assets and Returns on Assets: with very limited savings, liquid assets and social and political links, the poor have limited resources to recover from climate shocks. A single large shock or multiple small shocks will deplete the assets of the poor and push them below the survival threshold, and long term changes reductions in crop yields will reduce the returns on assets (land and labour).

Inequality: social exclusion, either deliberate or due to remoteness, means that the poor have limited access to new technologies, knowledge and infrastructure that can protect them from the impacts of changing climates, or the resources to recover from climate-related shocks. Studies have shown that women and children are particularly vulnerable to climate change, including reduction in the nutritional content of diets.

Climate change is largely driven by the natural and anthropogenic release of gases that trap heat within the Earth's atmosphere and change the chemical composition of the atmosphere and oceans. The most important gases linked to agriculture[1] are methane (CH_4), nitrous oxide (N_2O), carbon dioxide (CO_2)[2] and water vapour.

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[1] Other greenhouse gases are linked to industrial process: hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, nitrogen trifluoride

[2] Global Warming Potential (GWP), measured in carbon dioxide equivalent or CO_2e. one molecule of CO_2 = 1 CO_2e, methane (CH_4) = 23 CO_2e, nitrous oxide (N_2O) = 310 CO_2e

This results in:

- Temperature increase in the air, land and sea. Increased temperature will induce heat stress in livestock and plants, and increase the evaporation of water from the soil and plants (evapotranspiration), leading to water stress in crops. For crop production overall changes in temperature are not necessarily as important as changes in the number of hot days, reduction in cold days and increases in night temperatures as these have a direct effect on plant physiology, effecting the grow and yield of crop plants and species composition and productivity of rangelands and forests. Ocean warming will change the species composition of the seas, with temperature sensitive species, like corals, disappearing, and more adaptable species, like jellyfish, expanding their range. This is already having a direct effect on the diets and income of coastal communities.
- Precipitation. Though overall changes in the quantity of rainfall are important, for farmers when the rain comes (in terms of the crops water requirements), when it ends, how much comes in each rainfall event (intensity) and how predictable it is, are critical for crop production.
- The combined effects of changes in rainfall, temperature and potential evapotranspiration will change the length of the growing season for crops.
- Sea level rise: Sea levels are likely to rise by 11-77cm by 2100. This will drown productive agricultural land in coastal areas, increase the salinity of groundwater in coastal areas and increase the risk of flooding during storms.
- Increase in atmospheric carbon dioxide content. Where water and other nutrients are not limited this will favour crop production but may reduce the nutritional content of crops.
- Ocean acidification, changes in ocean circulation and salinity. These are interrelated. Ocean warming will change salinity, and in turn ocean circulation patterns. This will affect both the productivity of the oceans and the temperature and rainfall on land.

Concern Worldwide defines **Community Resilience as:** the ability of a community, household or individual to anticipate, respond to, cope with, and recover from the effects of shocks, and to adapt to stresses in a timely and effective manner without compromising their long-term prospects of moving out of poverty.

The increase in energy trapped in the system will lead to an increased incidence of extreme events, like floods, storms and droughts. Trying to reduce the emissions of greenhouse gases, or compensate for their effects, is termed **Climate Change Mitigation**. Agriculture is a major contributor to greenhouse gas emissions, accounting for around 14-20% of all global greenhouse gas emissions (GHG), equal to 6.8 gigatonnes of carbon equivalent, and consisting of 9% of global carbon dioxide emissions, 35-40% of global methane emissions, 64% of global nitrous oxide emissions. The main sources are methane from rice paddies and cattle, CO_2 released through deforestation to clear land for agriculture, and conversion of nitrogen in fertilisers and cattle manure to nitrogen oxides.

Concern has conducted carbon audits (2008 and 2013) and has mechanisms in place for country offices to measure their CO_2 emissions[i], however at a policy level Concern Worldwide has decide not, at this stage, to focus on climate change **mitigation**. Many of Concern's interventions actively reduce greenhouse gas emissions or fix (*sequester*) carbon within the soil and benefit the wider community (*public goods*). Conservation Agriculture can sequester significant amounts of carbon in the soil, integrated fertility management reduces the use and volatilisation of nitrogen fertilisers like urea, planting trees absorbs CO_2 from the atmosphere and SRI may reduce the level of methane released from rice fields. There are opportunities for smallholder farmers to benefit from carbon trading however Concern Worldwide does not currently have in-house technical expertise in carbon trading and there are risks that valuing carbon stocks may not benefit the poor, for example a landowner may be able to trade the carbon built up by poor tenant farmers.

Concern Worldwide's focus is on **adaption** to climate change, i.e. the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In agriculture the current term is "climate smart agriculture", closely linked to the concept of **resilient agriculture/ livelihoods**.

Modelling climate change and its effects on crop and livestock production

To understand how climate change will affect our beneficiaries, project planners need to review the latest data. The IPCC reports (IPCC 5 is the latest version) are a synthesis of current knowledge. The IPCC reviews the results of climate models (called General Circulation Models, GSM, of which there are over 24), research papers and other data sources and analysis and bases its predictions on much the models and analysis agree with each other. The IPCC predictions are based on **Emissions Scenarios.** These have been standardised and are used by most climate modellers.

IPPC Emissions Scenarios

A1 scenario family assumes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies that are shared across all regions, reducing regional differences and increased cultural and social interactions. The three A1 options are based on fuels used: fossil intensive (**A1FI**), non-fossil energy sources (**A1T**), or a mixture **(A1B).**

The **A2 storyline and scenario family** describes a very heterogeneous world based on self-reliance and preservation of local identities. Regional Fertility patterns change very slowly resulting in increasing global population. Economic development is regional and per capita economic growth and technological changes are more fragmented.

The **B1 storyline and scenario family** describes a convergent world with improved equity, with a global population that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid changes in economic structures toward a service and information economy, the introduction of clean and resource-efficient technologies, with global solutions to economic, social, and environmental sustainability.

The IPCC reports are extremely detailed and not easy to read so there are a range of reports, datasets and software that are produced for governments and agencies that are more accessible and specific to locations ("downscaled") (see appendix x). Before using these sources check that they have been updated using the IPCC 5 data sets and to review the predictions for each emission scenario.

Looking ahead is important for agriculture but even more important for long-term investments like tree plantations. To understand the impact of climate change on crop production the next stage is to run crop production software, like DSSAT, using the output from GSMs. The **IFPRI Climate Change in Africa** series of books is an example of this approach.

An alternative approach is to look for **Climate Change Analogue sites.** In theory someone, somewhere, is already experiencing the climate that the project area will experience in *x* years' time. If you can predict what the project site climate will be like in year *X* it should be possible to find "analogue sites", sites that are already experiencing these conditions and where farmers and herders have already adapted. These sites should give you clues as to what you need to do to adapt to climate change. There is a range of software available for finding analogue sites based on "similarity" scores (a statistical procedure). The online **CCAFS Climate Change Analogue software** http://analogues.ciat.cgiar.org/climate/ is probably the easiest to use.

Understanding local perceptions and local knowledge on climate change is important. Smallholder farmers in most of the areas that Concern targets are used to surviving in highly unpredictable conditions and innovative farmers may have already found local solutions to the effects of climate change, or elders may remember similar conditions when they were young. Concern Worldwide worked with the Natural Resources Institute, UK, to study farmer's perceptions of climate change in Sierra Leone. In some cases climate changes are outside the experience of anyone in the community and/ or changes in the social, economic, political environment, particularly population growth, may make it impossible to go back to traditional climate resilient systems.

Climate Smart Agriculture

Clearly "Climate Smart" can be applied to almost all agricultural systems. As cold areas get warmer or dry areas get wetter, new crops and be grown and crop productivity will increase. With a temperature rise >2°C much of southern Africa will no longer be able to grow maize, while Ireland and Scandinavia will become suitable for maize production. Crop responses to climate changes will depend on photosynthetic pathways, changes in the length of the growing season and changes in physiological growth "triggers", for example the number of hours <7°C triggers flowering in apples. Crops that use the C3 photosynthetic pathway (rice, wheat, potato, banana) are adapted to low light and CO_2 levels, and will do better where the climate will get wetter, cloudier, while C4 plants (maize, sorghum, millet, sugarcane, amaranthus), which require high light levels, photosynthesis 6x faster, and have higher Water Use Efficiency, can be expected to produce higher yields as CO_2 levels, sunlight and temperature increase.

> The 1st Global Conference on Agriculture, Food Security and Climate Change defined CSA as agriculture that: sustainably increases productivity, enhances resilience, reduces/ removes greenhouse gas emissions and enhances the achievements of food security and development goals (FAO 2010)

Changes in temperature will affect pest populations. Higher temperatures will increase the growth rates of some insects, fewer insects will die-off as winters get warmer and new pests will emerge. Dryer climates will however reduce the risks of some fungal diseases. The preferred option is to help farmers develop Integrated Pest Management (IPM) strategies for emerging pests and disease but Concern Worldwide has had little success promoting IPM, which is seen as too complicated by field staff and farmers.

> The Global CSA Alliance proposes that: "*CSA is a way to achieve short and long term agriculture development priorities in the face of climate change and it serves as an integrator to other development priorities. CSA seeks to support countries and other actors in securing the necessary policy, technical and financial conditions to enable them to:*
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> - *Sustainably increase agricultural productivity and incomes.*
> - *Build resilience and the capacity of agriculture and food systems to adapt to climate change.*
> - *Seek opportunities to reduce and remove greenhouse gases while meeting their national food security and development goals*."

Adapting to new crops and agronomic methods will require access to extension services, inputs and exposure to farmers who already practice CSA techniques, however the marginal farmers targeted by Concern Worldwide are those least likely to be able to access knowledge and resources.

Research carried out the CCAFS program has shown that women are currently receiving less information than men on agricultural practices and climate issues across Africa and South Asia.

In 2 regions of Kenya there were very low levels of awareness amongst women on soil and water conservation practices, however once aware women were just as likely, or more likely, than men to adopt CSA practices[3] , however women also experienced institutional (e.g. property rights) and market related constraints to adoption.

Climate change may affect the nutritional value of crops, impacting on the current drive to address chronic malnutrition (height for age) and micronutrient deficiencies through agriculture. Higher levels of CO_2 will, if water supply is adequate, improve carbohydrate production in crop plants. This is beneficial in terms of calorie production but may reduce the ratio of proteins and micronutrients to carbohydrates in grain. There may also be a reduction in the amount of micro-nutrients that crops take up from the soil, especially those required by humans that are not required by the plant. Higher temperatures and changes in fodder species will affect milk production and the distribution of animal diseases, particularly vector-borne diseases (ticks, flies and mosquitoes).

Climate Smart Field Activities

Ideal CSA practices would:

- Sustainably increase agricultural productivity and income, contributing to poverty reduction.
- Adapt, and build resilience, to changes in the climate.
- Reduce or remove greenhouse gases.

[3] Rainwater harvesting, agroforestry, crop residue mulching, composting, manure management, drought/heat/flood/salt tolerant varieties minimum tillage and cover crops.

The following are examples of CSA practices being promoted, researched or are under consideration, by Concern Worldwide.

Climate Smart Crop Production Options

Conservation Agriculture (No/ minimum tillage agriculture) (CA)

CA is based on three principles:

- **Minimise soil disturbance.** Instead of inverting the soil or making ridges, seeds are planted directly into the soil or in narrow furrows or basins. This avoids disturbing the soils natural structure, reducing the risks of soil erosion and the amount of soil moisture lost through evaporation. Direct planting also reduces delays in planting at the start of the rains.
- **Keep the soil covered.** The soil between plants should be covered by mulch (crop residues) or a green cover crop throughout the year. This retains moisture in the soil, reduces soil temperature, builds up soil organic matter and, by reducing the impact of raindrops and wind, prevents soil erosion, but can be difficult to achieve, or uneconomical, in areas where cattle traditionally graze crop residues and the dry season is too dry for cover crops to survive
- **Rotate the crops.** This reduces the risk of pest build-up, makes better use of soil fertility, and can contribute towards dietary diversity.

Results from Southern Africa and around the world show that CA has immediate biophysical and socio-economic effects such as increased water infiltration into the soil due to the protection of surface structure by mulch[ii], reduced water run-off and loss of top soil by maximizing the capture of rainfall and resulting increased infiltration from the ponding effect of the residues[iii], reduced evaporation of soil moisture as the crop residues protect the surface from solar radiation[iv], improved crop water balance[v], less frequent and intense moisture stress because of the increased infiltration and reduced evaporation[vi],[vii], reduced traction and labour requirements for land preparation and for weeding hence saving costs of manual labour, animal draft and fuel, depending on the farming system used[viii]. Field observations in Concern's CA projects, as yet uncorroborated by academic research, indicates that maize grown under CA is much more resistant to wind damage (lodging).

Long-term effects of CA such as increased soil organic matter resulting in better soil structure, higher pH, cation exchange capacity and nutrient availability, and greater water-holding capacity have also been reported[ix];[x]. Through early planting and the retention of soil moisture, CA helps farmers to cope with unreliable rainfall patterns and shorter growing seasons.

System for Rice Intensification (SRI)

Rather than growing rice in permanently flooded fields, SRI involves managing irrigation to ensure that the rice crop receives enough water for growth without the soil becoming waterlogged and anaerobic. Seedlings are transplanted at 9 days rather than 20 days, and are planted at a wide spacing to encourage the growth of additional shoots (tillering). SRI reduces the amount of irrigation water required so that irrigated rice can be grown in areas of limited water. The aerobic soil conditions and wider spacing encourages deeper root growth, reducing water stress on the rice. The amount of seed required is lower than for conventional rice production, an important consideration for farmers who rely on rice as their staple food.

The principles of SRI are being tested on other crops, for example sugar cane and wheat, in India and Ethiopia (System for Crop Intensification).

Salt and Flooding Tolerant Rice

Coastal areas are at increased risk of flooding with salt water, which destroys soil fertility. Several varieties of rice are now available that can tolerate saline soils and can be grown on fields that were contaminated by seawater. Increased rainfall in mountains combined with glacial melting, will increase the risk of flooding in river valleys, and the loss of crops. Two options for flood tolerant rice are now available. "Snorkel" rice rapidly elongates the stem in response to flooding, keeping the ear above the water level. Floating rice has a long root system but is only loosely attached to the soil. The plant floats on the surface of the water, anchored to the soil by the roots.

Agroforestry

Trees provide a wide range of products and services and can generally access water and nutrients at greater depth than most field crops. With the right combinations trees can be intercropped with field crops to improve soil fertility, reduce transpiration, maximise use of small plots and provide additional revenue. Fruit trees contribute to dietary diversity, but most trees need to be sold as timber or firewood in order to improve the livelihood of the household, so the benefits may be limited by market access issues. As trees are a long term investment security of land tenure is critical, as is selecting species, varieties and provenances that will be able to tolerate future climatic conditions.

Subgroups of Agroforestry Systems (AFS): major forms of agroforestry and their agroecological distribution in the tropics.

AFS subgroup	Major forms of agroforestry	Major agroecological distribution in the tropics
Tree intercropping	Alley cropping, improved fallows	Regions with >800 mm rain/yr;
	Multipurpose trees (MPTs) on farmlands	Throughout the tropics
Multistrata systems	Homegardens	Tropical wet (mostly elevations up to 1000 m asal)
	Shaded perennials	Wet, Moist & Montane regions with >1000 mm rain/yr
Silvopasture	Browsing, cut-and-carry	Tropical wet and moist regions
	Trees on pasture/grazing lands	Semiarid to arid regions
Protective systems	Windbreaks, shelterbelts	Tropical dry (arid, semiarid), coastal regions
	Soil conservation hedges	Sloping areas: moist, montane
	Boundary planting	Throughout
Agroforestry tree woodlots	Woodlots for firewood, fodder, land reclamation	Dry: firewood; land reclamation trop wet & moist: fodder; Land reclamation: eroded/degraded lands)

Source: Nair [18].

Rainwater Harvesting

Rainwater harvesting has been practised by humans living in semi-arid regions for at least 3,000 years, some rainwater collection ponds (tanks) in Sri Lanka in use today are up to 1,700 years old.

Rainwater harvesting is part of soil and water conservation and watershed/ catchment management, using a range of techniques to capture rainwater either for direct use on crops or to recharge groundwater. Concern Worldwide has been working with the International Centre for Research in Agroforestry (ICRAF) to introduce rainwater harvesting techniques used in Rwanda into Burundi. The rainwater is harvested from hillsides and roads and channelled into ponds where it can be used for irrigation. Using GIS software maps were created, with layers for rainfall, soil type, geology, topography, hydrology, population, roads, etc. GIS analysis was then used to shortlist potential sites for rainwater harvesting, from which the community made the final site selection. GIS provides a useful planning tool to integrate water supply projects, agriculture and watershed management activities to ensure that rainwater interventions are safe, and to maximise benefits: increased rainfall infiltration recharges aquifers and groundwater used for drinking water supply.

Examples of soil and water conservation techniques that are used by Concern Worldwide to harvest rainwater include:

- **Contour bunds / swales/ *Fanya juu* /*Fanya chini*.** Made out of soil, stones or trash, contour bunds slow down surface water flow, prevent rill formation and capture soil washed from upper slopes.
- **Demi-lunes.** Half-moon shaped ridges made in fields to trap rainwater and concentrate it around growing crops. Demi lunes are used throughout the Western Sahel and could be used in other semi-arid regions.
- **Sand dams**: dams built in the bed of sandy rivers. The dam traps water in the river sand for use during the dry season but allows water to flow over the dam when the river is in full flow, minimising the risk of damage to the dam during floods.

Farmer (and Herder) Managed Natural Regeneration (FMNR)

The traditional NGO picture of the Sahel (the semi-arid region south of the Sahara Desert running from the Atlantic to the Red Sea) is of widespread deforestation leading to desertification. Though vast areas of dry forest and parkland have been clear-felled to supply charcoal to urban areas, or to create fields, farmers in Niger manage the trees that naturally grow on their land by removing non-productive trees and thinning and pruning natural regrowth of beneficial trees (a process similar to the traditional medieval European forest coppice systems). Their crops benefit from windbreaks, lower temperatures, improved soil fertility from minerals transported from deep soil layers into the rooting zones of crops and nitrogen provided by leguminous trees, and increased soil organic matter from leaf litter and dead roots. Farmers have a sustainable income from firewood, construction wood and fruits. Herders in the Sahel also manage trees for fodder, cutting branches at head height (pollarding) to protect the new shoots from grazing animals, a practice that also reduces transpiration in drought years and ensures the survival of the trees, and rotating grazing to limit the amount of tannins in the leaves[4].

High Efficiency Irrigation

Irrigation, particularly supplementary irrigation, is critical if farmers are to adapt to drier climate and unreliable rainfall. Traditional irrigation systems normally use unlined canals. A large amount of water is lost from these canals and irrigation is only possible in flat areas below the water source. There are a range of more water efficient irrigation options. The most efficient option is drip irrigation. Though widely used in commercial horticulture worldwide, and by smallholder farmers in South Asia, drip irrigation has not been widely adopted by smallholder farmers in SSA. There are many reasons for this, but one key issue has been the lack of technical skills in drip irrigation of government and NGO staff. The few success stories are where commercial irrigation companies have been involved in the design, installation and training for drip systems, so the key to success may be closer collaboration with the private sector. Overhead sprinkler systems are also very efficient but are beyond the budget of poor farmers. In Pakistan Concern has tested rain guns (high power sprinklers). These have a lot of potential as they can be easily moved around fields and the fields do not have to be flat – hillsides and sides of sand dunes can be irrigated with rain guns.

Crop and Variety Diversity

By growing a range of crops farmers can hedge against climate risks, for example growing both maize and cassava. Under ideal conditions this not only provides insurance against climate risks but also increases dietary diversity and improves soil fertility management (crop rotation is a key part of CA). Unfortunately farmers with very small landholdings struggle to produce enough carbohydrate from an intensively managed monocropping and are reluctant, or unable, to allocate land for other crops.

In South Sudan the traditional approach to coping with climatic variability has been to plant a range of sorghum (*sorghum bicolor*) varieties: *cham*, early maturing, harvested in August; *alep cham*, second early; *unangjan*, maincrop; *maboior*, late maturing harvested in December, to ensure a yield in all but the most extreme weather conditions. In many traditional systems a household's fields are scattered to take advantage of different soil types, seasonal opportunities and to spread risks. Farmers who cannot access a range of land types may be at greater risk from climate change than those with diverse land holdings, as Concern Worldwide has seen in Western Zambia.

There is evidence from wheat farmers in Europe that, if the market does not require specific varieties, sewing a mixture of wheat varieties in the same field reduces the amount of fungicide that needs to be applied. These techniques have potential for wider trials and dissemination as part of climate smart agriculture for areas that will experience greater climatic uncertainty and for areas that will have higher rainfall (and therefor a higher fungal disease risks).

[4] Tannins are plants' protection against herbivores. Tannins coagulate the saliva, making the leaves indigestible. Plants produce more tannins when grazed and grazed plants can signal to neighbouring plants to also increase tannin levels.

Plant Breeding

Drought tolerant varieties

There are three main strategies for producing drought tolerant varieties:

- **Drought escape**. Varieties that complete water-critical stages of development before the rains end. Concern distributes quick maturing varieties as a strategy to adapt to shortening growing seasons, however quick maturity also means that the plant has less time to assimilate carbohydrates and therefore yields are lower.
- **Drought avoidance:** mechanisms that operate even in the absence of drought, for example breeding for deeper root systems.
- **Drought tolerance:** responses triggered by drought (water stress). These include dormancy, osmotic adjustment to maintain turgor pressure (internal cell pressure that helps the leave keep its shape), the ability to survive dehydration, changes in leaf anatomy that reduce water loss, prevent overheating and protect the chloroplasts from excessive sunlight levels (wax coatings that reduce water loss, leaf rolling, leaf hairs). "Staygreen", where the leaves remain green until harvest, is not in itself a tolerance mechanism but is often associated with drought tolerant varieties. Water storage, usually in the stem, that can be utilised by the filing grains. Plant enzymes operate efficiently within a narrow temperature range so drought tolerant plants tend to have enzymes that can function at higher temperatures (heat tolerance).

Concern Ethiopia has been working with the National Agriculture Research Institution to develop and promote drought tolerant taro, a crop more normally associated with wetlands.

Salt Tolerance

High levels of salt in the soil have a similar effect on plants as droughts. As salt levels increase it becomes harder for plants to extract water from the soil. To overcome the effects of salt plants have to use more energy, resulting in lower yields. Salt can be removed from the soil by planting highly salt tolerant species, like *Atriplex*, which are harvested and can be used as fodder or fuel. In Israel *Atriplex numilaria* is eaten as a green vegetable. Some crops, like barley, cotton, sugarcane, oilseeds and grasses, are relatively salt tolerant. Salt tolerance also seems to increase with ploidy level[5]; hexaploid bread wheat is more tolerant to salt than durum (tetraploid) and einkorn (diploid) wheat. In Brassicas, tetraploid species are more tolerant than diploids. Late maturing, tall and coarse grain rice varieties tend to be more tolerant and in sugarcane land races are more tolerant to salinity than high yielding cultivars. Plants can overcome the osmotic gradient in saline soils by increasing the levels of sugar in plant cells: sugar beet is very salt tolerant, as are sweet watermelon varieties. Growing plants from seed in saline conditions can also create tolerance (salt shock treatment), for example for tomatoes.

In Bangladesh Concern has proposed an innovation option for farmers affected by increasing salinity: "Poly-bed Nutrition Gardens". Farmers harvest and store rain water during the monsoon season in tanks that are used for small fish ponds, horticulture and domestic consumption. The topsoil is removed, a polyethylene sheet laid over the subsoil, and the topsoil replaced. The sheet acts as an impermeable barrier, preventing salinity intrusion from the underlying soil and retaining soil moisture.

Participatory Variety Selection

New varieties are normally tested on research farms, where they are grown under ideal agronomic conditions. Promising new varieties often fail to live up to expectations when planted by smallholders in less than ideal conditions (poor soils, late planting, little or no inputs, no supplementary irrigation, delays in weeding, etc.). Concern therefor introduces new varieties through a process of participatory variety selection. A few lines of a new variety are planted alongside traditional varieties, often as part of a Farmer Field School, and given the same treatment as local crops. Farmers assess a range of traits through the growing season, including resilience to climatic factors, so that their choice

[5] Ploidy level: most organisms have two copies of each chromosome (diploid), one from the father and one from the mother, in the nucleus of all their cells except those cells involved in sexual reproduction (gametes). In rare cases species may have three copies of each chromosome (triploid), four sets (tetraploid), six (hexaploid), etc.

of seeds for the next season is based on field experience. This needs to be linked with support for both traditional seed systems and input supply chains so that farmers have access to a range of crop varieties.

Participatory Plant Breeding

Farmers have been breeding their own varieties for 10,000+ years through the selection of seed from the best plants at harvest. Modern plant breeding is based on selecting the offspring from a very high number of crosses. Typically hundreds and thousands of varieties will be crossed, creating a huge range of potential genetic variability in the offspring. Though breeders try to select the best offspring from these crosses for multiplication, and new techniques have made the job easier (marker assisted selection), inevitably many offspring with good potential will be missed, so the process is expensive and rather inefficient.

Although the varieties produce by conventional breeding have high yield potential and are resistant to, or tolerant to, key diseases, they are not well adapted to local stresses, low input farming and local soil conditions. Critically, they have been bred for maximum cereal yield and so lack some of the traits that are valued by farmers. By helping key farmers develop their own varieties through to Participatory Plant Breeding (PPB), now called Client Orientated Plant Breeding (CoB), Concern Worldwide can help farmers to get the best of both worlds: "tailor-made" new varieties with good yield potential and resistance to current disease threats that are well adapted to local growing conditions, especially climatic factors, and which possess the traits that farmers value. The process is relatively simple, with low costs and high potential benefits, though it requires a long-term commitment.

Crop Storage and Processing

In theory higher production during good years should help compensate for bad years if the crops can be stored, or monetised and the proceeds banked. Even if there is a surplus available for storage after debts and loans have been cleared and immediate costs paid, large amounts of crops are lost during storage due to insects and rodents[6]. There is also a hidden risk from fungi that infect stored crops and produce aflatoxins, toxins linked to liver cancer in adults and stunting and retarded mental development in children. Where rainfall is expected to increase due to climate change aflatoxin levels may also increase.

To reduce post-harvest losses Concern trains farmers in good storage practices and pilots improved storage techniques: grain silos, grain bins, double-bagging, solarisation, sun drying and hermetically sealed bags. NGOs like Concern Worldwide have often promoted community seed and grain storage, with mixed results. Success is linked to targeting the storage technology to the appropriate "social management unit" for crop storage. Village seed and grain stores are unlikely to work if the traditional social management unit is the household or extended family. Concern Worldwide is piloting field test kits for aflatoxins and, where a risk is detected, trains farmers in simple control measures.

Despite improved crop storage, in reality few of our farmers will be able to produce large enough surpluses even in good years to cover the bad years.

Seed Priming and Transplanting

These are a drought escape mechanism. Traditionally used for rice and, in Northern Nigeria, for sorghum transplanting works for a range of crops. The seeds can be germinated using small amounts of water (waste water from the household) and then transplanted when the rains start. Concern piloted transplanting sorghum in Northern Uganda. Transplanting was more labour intensive but the yields were good, however there was little uptake by farmers. The results were Seed priming involves soaking the seeds for 12 hours before planting. Both approaches give the plants a head start so that they can reach maturity 1-2 weeks earlier than conventionally planted seeds, increasing the chance of a harvest even if the rains end early.

[6] Determining post-harvest crop losses in the field is very difficult, but losses are typically around 15%, rising to 30% with severe insect infestations.

Soil Fertility Management

Higher temperatures will reduce soil fertility by increasing the rate that soil nutrients and carbon are oxidised, and reducing the level of activity by soil micro and macro fauna. Nitrogen fertilisers and farmyard manure release greenhouse gasses when applied to fields, while making and transporting fertilisers uses large qualities of fossil fuels. Farmers therefore need to manage soil fertility carefully and apply fertilisers in ways that maximise benefits to the plants while minimising losses from volatilisation and leaching (Fertiliser Use Efficiency).

Before adding nutrients farmers need to know the pH of their soil (which partly determines the availability of soil nutrients) and the nutrient status, so Concern field office have soil test kits and some offices have commissioned professional soil surveys. Applying organic matter to the soil, through mulch, compost, farm yard manure and leaf litter from agroforestry, stabilises the soil structure and acts as a sponge, holding nutrients in the soil and reducing losses through leaching. Using the same planting basins and rip lines each season in Conservation Agriculture systems concentrates the nutrients in the plants' root zone. Concern Worldwide has been promoting micro-dosing fertilisers, a precision agriculture technique developed by the International Centre for Research in the Semi-Arid Tropics (ICRISAT). Instead of broadcast or band applications of fertilisers, precisely measured quantities of fertiliser are applied to each planting station. Concern Worldwide is also helping farmers to experiment with other soil fertility management practices like biochar, mulching with *Tithonia diversifolia*, deep placement of fertilisers in rice, green manures (nitrogen-fixing crops intercropped to suppress weeds and improve soil fertility), intercropping and relay cropping.

Commercialisation of Drought Tolerant Crops.

Climate change has stimulated interest in increasing the use of naturally drought tolerant crops (Xerophytes). Some crops can withstand mild droughts (cassava, sorghum, chickpeas and pearl millet) but currently few commercial crops are fully adapted to drought. The best known drought tolerant commercial crops are sisal, pineapple (which utilises the highly water efficient Crassulacean acid metabolism pathway for photosynthesis), aloe vera and jojoba. Thought not a true xerophyte, chickpeas can often be grown during the dry season on the residual moisture left in the soil after the main crop has been harvested.

Wild species, like *Balanites*, can be very drought tolerant and Concern has started working with the World Agroforestry Centre in Chad to identify drought tolerant wild fruit species, select the best individuals for collecting seeds and training farmers in new nursery techniques that reduce the time required for wild fruits to come into bearing.

Sisal shows promise as a drought tolerant cash crop. Planted in the 19th C in semi-arid regions to produce fibre for sacks and ships' ropes, the introduction of nylon and polypropylene fibres led to the collapse of the sisal industry. In recent years demand has risen as new uses are found for sisal. The fibres are used to make seats and sound-proofing panels for high-end cars, special paper, geotextiles, carpets, sisal sacks are now preferred for some crops as they reduce the risk of aflatoxin contamination[7] and even dart boards. Cortico-steroid drugs can be extracted from sisal and research at the University of Asmara, Eritrea, financed by Concern Worldwide, showed that sisal pulp (a by-product of sisal fibre extraction) can, if sun dried and the small fibres removed, provide a good quality, easily stored, animal feed that boosts milk production in cows. Concern Worldwide currently plants sisal in semi-arid areas to stop soil erosion and reclaim degraded land, so the next stage is to help farmers extract the fibres by hand or with simple machines for sale and utilise the pulp to improve milk and meat production from their livestock. A sisal project by Oxfam UK in Tanzania enabled farmers to earn up to $2,000 per year from sisal, so Concern Worldwide will be following the Oxfam model in Haiti and, if successful, in Somaliland.

[7] Though sisal sacks, due to their oily smell, should not be used for high value crops like coffee – jute sacks are preferred.

Climate Smart Livestock Production Options

Pastoralism

Nomadic pastoralism is inherently Climate Smart, as it evolved to enable communities to exploit environments, often semi-arid with heterogeneous and highly seasonal grazing resources, that are unsuitable for more intensive livestock production, or the production of grains to feed livestock: herders can take their animals to the rain but it's much harder for farmers to bring the rain to their crops. For the system to work herders must be able to move their animals to where the grass is greener. National boundaries, game reserves, urbanisation and conflict are reducing mobility. In Northern Kenya Concern Worldwide has facilitated community dialogue to reduce tension and ensure reciprocal access to grazing resources.

Cattle raised by pastoralists may produce large amounts of methane per animal, but this has no significant effect on the net production of Greenhouse Gases per km^2. Grass not eaten by cattle would be eaten by other methane producing herbivores, including termites, or burnt in seasonal bush fires, releasing CO_2.

Livestock Diversity

Climate Change will affect livestock production directly, through heat stress and water shortages and indirectly through changes in grassland species to more drought tolerant, but less digestible, species and changes in the distribution of animal diseases. Over much of Africa traditional cattle breeds have been crossed with highly productive Friesian Holsteins. This has resulted in a large increase in milk production but the cross-bred animals need large quantities of water and are vulnerable to heat stress. Similar issues are becoming apparent for sheep and goats.

In areas of Africa and Asia that will get drier, farmers will have to move to keeping livestock, and herds will need to adjust their herds, with camels replacing cows in areas predicted to become very dry. Camels are drought tolerant and mobile; goats have fast reproduction cycles and can feed on perennial fodder trees, and sheep have a ready market in Islamic cultures.

As some traditional breeds are better adapted to projected climate changes, so protection the genetic diversity for dryland breeds is an important CSA strategy, as well as providing a source of genes for cross-breeding Concern Kenya has been working with the International Livestock Research Institution to protect the Red Maasai sheep breed. Sheep are generally very hardy and, where there are large Muslim communities, provide a good income. To improve meat production and quality[8], the traditional Red Maasai sheep have been crossed with other breeds. This has resulted in animals with a thick coat that is difficult to keep free from parasites, increases heat stress and there has been a reduction in natural resistance to intestinal worms.

Improved Animal Health Services

Research by Tufts University confirmed what livestock keepers have always known, keeping lactating animals alive during droughts protects children from chronic and acute malnutrition. To survive droughts animals need to be healthy at the start of the drought, through access to preventative healthcare (deworming, vaccinations, tick and fly control), access to water during a drought, and access to feed. In many countries Concern Worldwide trains members of the community as community animal health workers and provides them with basic veterinary kits. In North Kenya Concern Worldwide has taught herders to collect and store hay to feed lactating animals during droughts.

Insurance

Traditional agricultural insurance has high overhead costs and will probably never be viable for smallholder farmers so NGOs and research institutions have, in partnership with the insurance industry, tried to develop alternative insurance

[8] Urban markets in Kenya prefer "marbled" meat, meat with the fat distributed throughout the muscle, rather than the layers of fat associated with some breeds. Muslims communities often prefer large white sheep breeds for the Eid celebrations.

models. The most promising is Index Based Insurance. Index Based Insurance is usually based on climatic factors, with farmers receiving a pay-out if rainfall falls below a minimum. Payments are based on data from a trusted third party, usually rainfall or satellite data which avoids the need for insurance companies to send staff to the field to access losses. Index Based Insurance has taken-off in Kenya and India (where it is part of government policy and is supported by a range of micro-insurance research and training institutions and consultants), and there are pilots in many other countries. Usually Index Based Insurance only covers the value of the inputs, so while it encourages farmers to invest in new technology it does not protect farmers' food security in the event of a drought or flood. Concern Worldwide has decide not to pilot insurance directly, as Concern has no in-house insurance specialist and the Worldwide picture for IBI is not clear. Concern Worldwide has proposed to pilot insurance in partnership with specialist institutions, for example Concern Worldwide has been in discussion with the International Livestock Research Institution (ILRI) to pilot Index based livestock insurance for pastoralists in Northern Kenya.

Early Warning Systems

Given an adequate supply of nutrients crop yield is determined by the amount of sunlight a plant receives, the amount of water flowing through the plant and the temperature. By measuring rainfall, temperature, evapotranspiration at critical plant growth stages (Concern provides either traditional rain gauges or automatic, weather stations that link to a PC for sites were government met data is unavailable) it is possible to estimate the final harvest. In some cases direct measurement of met data can be replaced by remote sensing, for example the Normalised Difference Vegetation Index (NDVI), a measure of the ratio of red/far red radiation reflected by the Earth's surface, can be determined from satellite photographs and provides an estimation of photosynthesising vegetation cover. Traditional agriculture text books contain tables for calculating expected yields from meteorological data but these have been largely replaced by software.

Food supply is determined by trade flows and storage as well as by local crop harvests, so early warning systems also need to track market prices and proxy indicators like livestock sales.

Most Early Warning Systems, like the system that Tufts University is developing for Concern Worldwide in Chad, are based on a range of indicators, including local community indicators, with each indicator weighted by the strength of the correlation between the indicator and food availability. Local early warning systems need to link in with national regional systems, like the USAID run FEWSNet.

Farmers need to be able to access Early Warning information in a form and language that they understand, and from a source that they trust. Participatory data collection and analysis can help people to understand and trust the warnings. Concern Worldwide has been piloting the use of Information Technology to both collect information from the community and to disseminate warnings. The warning need to be linked to preparedness planning: when a drought is predicted what action should farmers and herders take, for example herders may sell off some stock while the animals are still in good health (destocking)?

Disaster Risk Reduction and Community Planning,

Climate change is predicted to increase the frequency and intensity of hydro-meteorological hazards (floods, droughts and wet landslides) and some biological hazards (human, crop and livestock pests and diseases). Furthermore, climate change itself can be seen as a hazard, but it can also be looked at as part of the 'wider context' that magnifies risk.

While this paper focuses on the role of agriculture in addressing and adapting to climate change, not all hazards will be adequately addressed only through agricultural interventions; to protect food production it is also necessary to implement disaster risk reduction (DRR).

An essential first step is to undertake a risk analysis, where risk is the **probability of a hazard occurring x the impact of the hazard.** The impact of a hazard is closely related to the vulnerability of the exposed people, as well as the intensity and scale of the hazard itself. In a risk analysis it is important to identify and analyse all hazards, the influence climate change and other wider context issues has on hazards, the causes of vulnerabilities of the people we work with, and their capacities to address hazards. See Concern's Risk Analysis Guidelines for more information on how to do this. This forms the basis for informed decision making on how to adequately protect food production, marketing systems and other livelihoods.

Climate Smart Agriculture (CSA)

Following on from the risk analysis, farmers and pastoralists must identify how they can mitigate risks (either by reducing the scale, intensity and frequency of hazards, or by reducing their vulnerability to them), prepare for coping with and recovering from events that damage food production and livelihood systems (which includes anticipating them using early warning systems as described above) and using advocacy to change policy and other wider context barriers (including, for example, land tenure issues or access to social protection) if necessary. Concern Worldwide's focus is to ensure that women and disadvantaged groups take part in community DRR planning and that their issues and perceived risks are addressed by the plans.

Concern Worldwide is implementing the EU funded Paribatan project in Bay of Bengal coastal communities (India, and Bangladesh) that is directly working on reducing the risks to communities of climate change and natural hazards, reaching 1,225,750 total beneficiaries across both countries. With participating communities the project has developed the Bay of Bengal Charter on Climate Change as a guide for policymakers.

Energy

Like most development NGOs, Concern Worldwide has supported many projects over the years to improve the energy efficiency of cooking stoves. As a result of this work energy efficient stoves are now available in markets in most urban areas of Sub Saharan Africa and Asia but uptake after the end of NGO support has been very limited in rural areas. Concern Worldwide has produced a guide to fuel efficient stoves based on the learning from the field to reduce the risk of reinventing the wheel.

It is almost inevitable that however efficiently extremely poor people manage their energy use they will still need access to more energy if they are to escape from extreme poverty. Concern Worldwide has worked on some alternative power sources. Photovoltaic power has been used to run irrigation and drinking water pumps (Tanzania and Mozambique) and provide energy for farmer training centres (Liberia) and fish coolers (Haiti). Concern Worldwide has supported micro-hydro (<=100kW) electrical power schemes in Afghanistan and pico-hydro "run-of-stream" projects[9] (<5kW) in DPRK.

In Pakistan Concern has tested an integrated biogas system. Farmyard manure is fed into the digester to produce methane. At night the methane is used for cooking and during the day the methane is used to power a diesel irrigation pump. The system is linked to the irrigation system. The slurry is fed into a tank, where it is mixed with irrigation water to provide fertigation. The benefits are numerous: reduction in firewood use and indoor smoke, reduction in diesel consumption, reduction in the amount of artificial fertilisers required, reducing in methane emissions from the cattle manure (and urea fertilisers), unfortunately the Pakistani system[10] is far too expensive for poor farmers unless subsidised by the government.

In Malawi Concern is working with a private company, BERL, to produce oil from Jatropha grown as hedges around farmers' fields that will be used to produce diesel and kerosene biofuel blends for the local market. In the DPRK Concern has helped the Academy of Agricultural Science test sweet sorghum, a crop that provides both grain for human consumption, sugar that can be converted into biofuels, with a residue that provides high quality animal fodder.

The Role of Governments

Climate Smart Agriculture needs to be high on the agenda of all governments, and all countries now have National Climate Change Adaption Plans in place. In countries that are already suffering from the effects of climate change, for example Bangladesh, CSA is given high priority, but in other countries, particularly where the effects are more long term or not well understood CSA tends to get displaced by short term issues like fertiliser subsidies. CSA has not been part of Concern Worldwide's advocacy agenda, so there is limited internal knowledge on national policies and international commitments; however this will change through Concern Worldwide's work on **resilience**. There are ongoing disputes at the international level on setting CO_2 emission targets, however for those countries that have agreed targets CSA provides opportunities to meet the targets, and mitigation may provide a revenue source to fund CSA.

[9] Enough to light a house and run a radio. The direct flow of the stream can be used without the need to build a dam.
[10] There are a range of cheaper biogas options available in other countries.

There are opportunities for national level advocacy. In Pakistan the government provides grants for High Efficiency Irrigation; however land ownership clauses exclude many of the extreme poor that Concern targets and the funding is largely for drip irrigation. To increase the benefits for the poor, Concern could advocate for more funding for rain guns and a relaxation of the land ownership requirements. The initial costs of biogas are too high for poor farmers. India subsidies biogas and other countries could benefit from following India's example for biogas, and also provide subsidies for small wind turbines, photovoltaics, micro/ pico hydro power systems. As well as directly benefiting poor households, biogas subsidies should, in theory, have numerous national and strategic benefits: helping governments to meet their GHG emission targets, reducing the use of fuelwood and reducing the need to import or mine fossil fuels.

Concern Worldwide is part of a consortium of International NGOs, the CSA Alliance, which aims to expand CSA practices to 6 million farmers in SSA within the next seven years.

<u>What's Happening Where</u>

	Crop Production												Water			Agro-forestry		Livestock Production					Energy			
	CA/ CA with trees.	SRI	Flood tolerant crops/ varieties	Crop and crop variety Diversity	Drought Tolerant crops/ varieties	Quick Maturing Varieties/ drought avoiding varieties	Salt Tolerant crops	Participatory Variety Selection	Seed Priming	Transplanting	Soil Fertility Management	Post-Harvest Storage	High Efficiency Irrigation	Rainwater Harvesting (on & off farm)	Watershed / Catchment Management/river training	Agro forestry	Farmer Managed Natural Regeneration	Pastoralism	Animal Health	Livestock breed conservation/ Livestock Diversity	Rangeland Management	Early Warning Systems	Fuel Efficient stoves	Power generation	Biofuels	Insurance
Current																										
Afghanistan		✓										✓		✓	✓	✓					✓		✓	✓		
Bangladesh			✓				✓								✓							✓				✓
Burundi													✓	✓									✓			
CAR																										
Chad	✓					✓								✓		✓	✓	✓				✓				
DPRK	✓							✓			✓	✓		✓		✓			✓					✓	✓	
DRC																										
Ethiopia					✓							✓		✓												
Haiti	✓				✓																					
Kenya													✓					✓	✓	✓	✓					✓

Climate Smart Agriculture (CSA)

Lebanon																										
Liberia																								✓		
Malawi	✓										✓		✓						✓						✓	
Mozambique	✓	✓											✓		✓									✓		
Niger														✓												
Pakistan													✓											✓		
Rwanda																										
Sierra Leone												✓			✓								✓			
Somalia & Somaliland	✓				✓						✓	✓		✓												
South Sudan				✓																						
Sudan						✓													✓				✓			
Syria																										
Tanzania	✓							✓																		
Turkey																										
Uganda																		✓								
Zambia	✓									✓	✓												✓			
Former																										
India															✓											✓
Angola	✓										✓								✓							
Cambodia		✓																								
Zimbabwe	✓												✓													

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