Pacific-German Regional Programme on
Adaptation to Climate Change in the Pacific Island Region

CLIMATE CHANGE KIT

Vanuatu

gtz

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Preface

"By reducing the vulnerability of Vanuatu's vital sectors and communities now to current climate-related risks should place the country in a better position to cope with future climate change and to build sustainable ni-Vanuatu communities. The ideal approach to adaptation in Vanuatu is a pro-active, no-regrets approach which encompasses measures and strategies which can be implemented in the present with the aim of reducing vulnerability in the future. A no-regrets approach is one which would be beneficial to Vanuatu even in the absence of climate and sea-level change." His Excellency the President of the Republic of Vanuatu in opening the first National Conference on National Adaptation Programme of Action in January 2005.

Vanuatu is among countries in the Pacific region that are most vulnerable to the risks of climate change, climate variability and sea level rise. The livelihood of our people and economy which are interwoven, shaped and driven by climate sensitive sectors, the effect of climate and sea level change are already very real and pose a tangible threat to the future socio-economic well-being of Vanuatu.

The very diverse environment that once sustained our forefathers with great abundance and continues to play a central role in the livelihood of ni-Vanuatu has begun to change. Crops in subsistence gardens are showing signs of stress, prolonged and enhanced drought conditions are resulting in water shortages, rising sea levels are slowly eating away our shores, threatening communities and underground water sources, often the only source of water (apart from rain water) in some of our small islands. Increasing population growth leading to increased pressure on land resources coupled with the shift in social values, land use practices and changing attitudes to the environment, increase the potential vulnerability of Vanuatu to climate change and sea level change.

Climate related disasters are one of the main hindrances to economic development in Vanuatu and this will certainly continue and could predictably be exacerbated by climate change. As expected, the degree and nature of vulnerability varies, in certain degrees between islands but the impacts would certainly be experienced in the livelihood of all people as well as climate sensitive sectors such as agriculture and livestock, coastal zones and reefs, water resources, health, forests and biodiversity.

Adaptation to climate change, variability and sea level change is an urgent need for Vanuatu. This report looks at those vital development sectors of Vanuatu and calls upon the government, communities, provincial authorities, non-government organizations and the private sector to strengthen capacity to deal with climate change, mainstream adaptation in national planning, modify policies and legislations where necessary to become more adaptation friendly, support the capacity for adaptation and implement measures to reduce vulnerability to climate change.

REPUBLIC OF VANUATU
MINISTER OF INFRASTRUCTURE AND PUBLIC UTILITIES
MINISTRE DE L'EQUIPEMENT ET DE L'AMENAGEMENT

Honorable Edward Nipake Natapei TUTA FANUA' ARIKI
Deputy Prime Minister
Ministry of Infrastructure and Public Utilities

How Climate Change impacts us in the PACIFIC

CLIMATE CHANGE AFFECTS:

1. Our fresh water,
2. Our Agriculture,
3. Our Forests,
4. Our Biodiversity,
5. Our Health,
6. Our Coastal and Marine Resources
7. and our Economy

Why we should be concerned?

Our islands may be Paradise now,but every year the adverse impacts of climate change increase. If urgent steps are not taken to decrease 'Global Warming' soon, we may lose our island way of life.

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Design and Cartoons by John Robinson, 2004

Climate Change and how Communities need to respond to it in the PACIFIC

Our Pacific needs us!

Let's join together to combat the effects of "Global Warming" the cause of climate change, before it destroys our island paradise and our way of life forever!

What we can do:

Our fresh water,

Mend leaky water pipes and taps.
Re-cycle water when watering gardens.
Turn off taps when not in use.
Store water for emergencies.
Don't pollute rivers and streams.

Our Agriculture,

Change planting times to fit with the weather.
Plant more than one type of crop.
Use natural compost, not chemical fertilizers.

Our Forests,

Replant natural forests.
Plant a tree (local species).
Show support for forest conservation.

Our Biodiversity,

Support and respect protected areas.
Keep protected areas clean.

Our Health,

Clean up yards and destroy mosquito breeding grounds.
Boil drinking water.
Exercise and eat a healthy diet.

Our Coastal and Marine Resources

Protect coral reefs.
Plant mangrove and coconut trees.
Do not build too close to coastline.

Our Economy

Encourage Eco Tourism ventures.
Prevent over exploitation of natural resources.
Use renewable energy.

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Design and Cartoons by John Robinson, 2005

The Greenhouse Effect

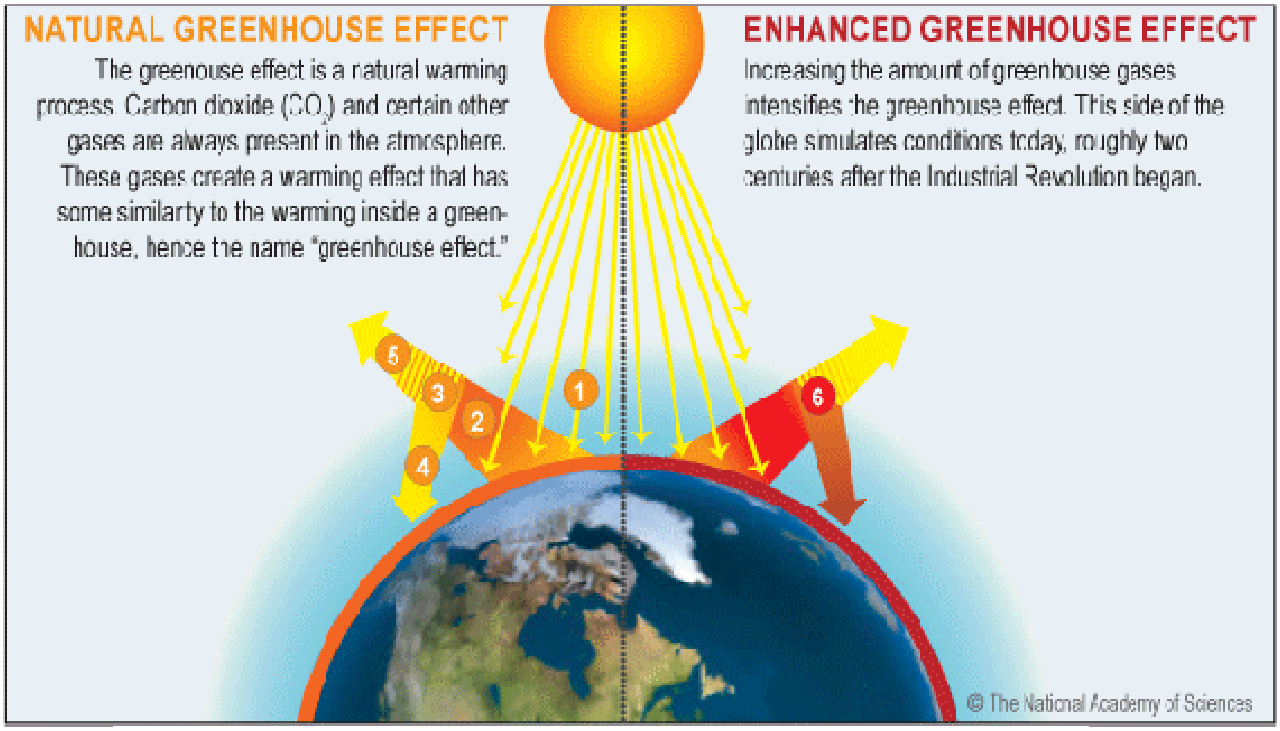
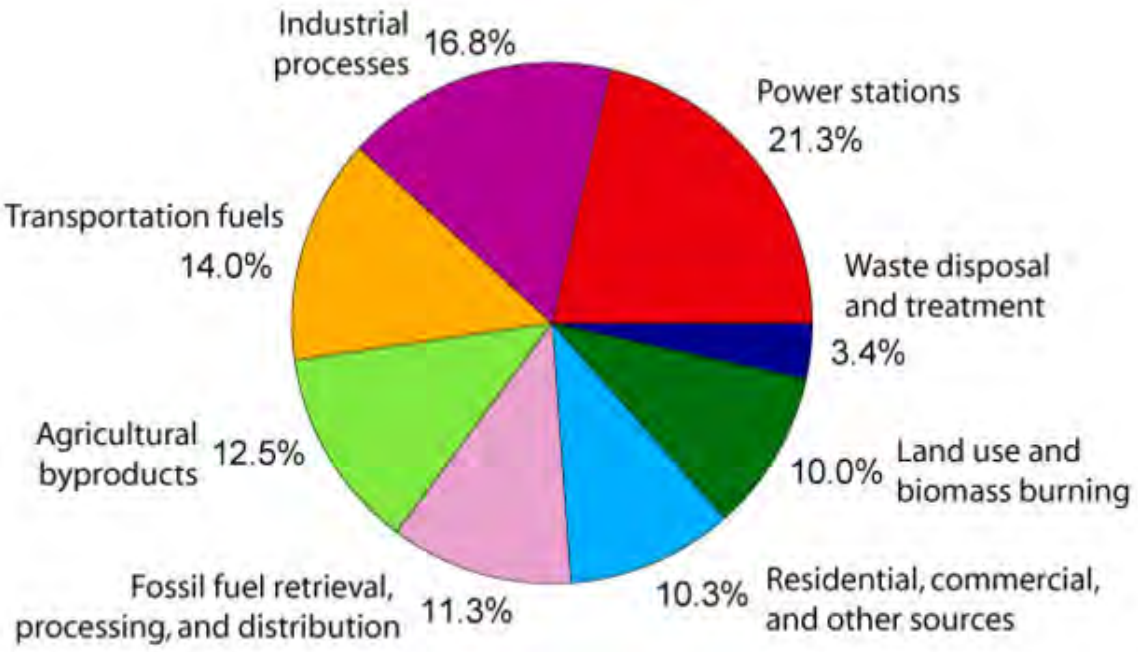


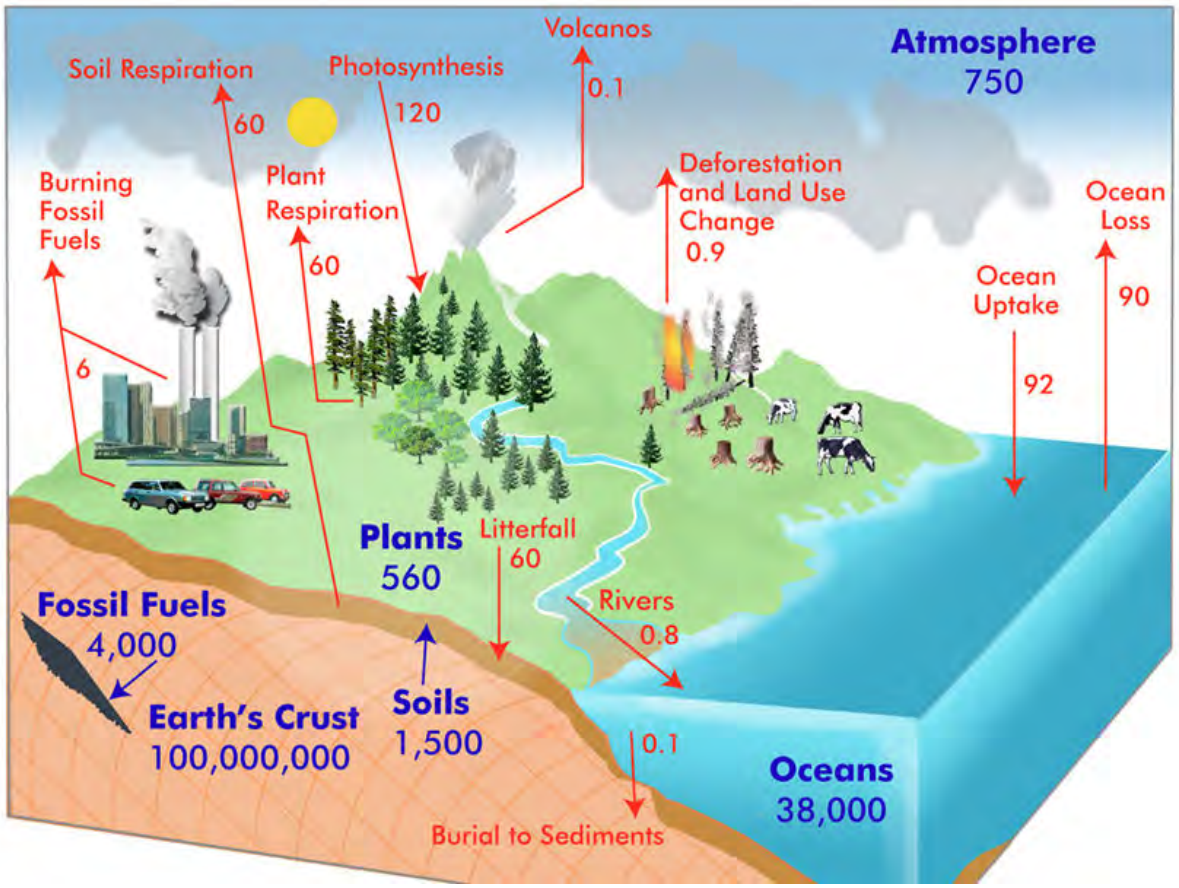
Illustration of the greenhouse effect (courtesy of the Marion Koshland Science Museum of the National Academy of Sciences). Visible sunlight passes through the atmosphere without being absorbed. Some of the sunlight striking the earth 1 is absorbed and converted to heat, which warms the surface. The surface 2 emits infrared radiation to the atmosphere, where some of it 3 is absorbed by greenhouse gases and 4 re-emitted toward the surface; some of the heat is not trapped by greenhouse gases and 5 escapes into space. Human activities that emit additional greenhouse gases to the atmosphere 6 increase the amount of infrared radiation that gets absorbed before escaping into space, thus enhancing the greenhouse effect and amplifying the warming of the earth.

Image Source: The National Academy of Sciences

Ol GreenHouse Gas oli trapem hit, olsem wan blanket we i raonem wol. Taem yumi putum moa GreenHouse Gasses i ko long atmosphere, blanket i kam moa thick, mo hemi trappem moa hit, mekem se temperaja blong wol i ko antap. High Temperaja i kosem moa ren, moa disease, meltem ice mo mekem sea level i ko antap mo plante narafala samting. Sam impact oli no gud, be sam oli gud.

Wanem i kosem GreenHouse Gas i ko antap long Atmosphere?





Greenhouse Gasses: Carbon Dioxide, Methane, Nitrous Oxide, Sulfur Hexaflouride, Water Vapour

THE LIKELY IMPACTS OF CLIMATE CHANGE AND CLIMATE VARIABILITY ON AGRICULTURE AND FOOD SECURITY IN VANUATU

According to FAO (2007a) the croplands, pastures and forests that occupy 60 percent of the Earth's surface are progressively being exposed to threats from increased climatic variability and, in the longer run, to climate change. Abnormal changes in air temperature and rainfall and resulting increases in frequency and intensity of drought and flood events have long term implications for the viability of these ecosystems.

Although there is limited historic data on which to base a more reliable assessment of the likely impacts of climate change on the agriculture sector and on food security in Vanuatu, a review of a number of reports and publications suggest that the following impacts are likely to be realized for the various components of the agriculture sector and for food security in Vanuatu. A clearer assessment of the likely impacts of climate change and climate variability on small islands of Vanuatu is presented in Table 6.

CROPS

Although the impacts of climate change on agricultural crops in Vanuatu are not well understood, general knowledge and anecdotal observations suggest that changes may be detrimental to agricultural production and hence national food security.

Climate related incidences are already affecting crop production. Increased temperatures, more frequent and prolonged dry conditions, increased variability of rainfall, salt water intrusion, droughts, soil erosion and cyclones have been experienced in the past few years. Pest activities have also increased with yams being the crop most affected. With projected temperature increases to 28.8 degrees and 29.7 degrees in 2050 and 2080 respectively, heat tolerance thresholds of crops are likely to be reached and this will most likely induce heat stress, wilting and crop failure. Subsistence crop production may fall as a result and in turn threaten food security on the island.

Both commercial and subsistence agriculture in Vanuatu are based on rain-fed agricultural production systems. Changes in rainfall, high intensity storm events,

increased evaporation and more pronounced dry seasons, could have severe impacts on agriculture crop production. Intense rainfall during planting seasons could damage seedlings, reduce growth and provide conditions that promote plant pests and diseases. More pronounced dry seasons, warmer temperature and greater evaporation on the other hand could induce plant stress reducing productivity and harvest and subsequently, affect food security.

The alternate scenario of increased rainfall could have equally severe impacts with water-logged soils decreasing agricultural production, while increased humidity and rainfall could provide ideal conditions for the proliferation of a number of plant pathogens. These conditions could lead to declining agricultural production and this would adversely affect both the country's economy and food security.

The farmers interviewed during the undertaking of this study commented on some plants flowering earlier than usual while others are fruiting much later than normal during the past 3–4 years. Another farmer referred to the south east trade winds that was still blowing at end October when traditionally this would have ended in August/September each year. Whilst these farmers agree that climate change may have something to do with these changes, it was difficult for them to determine the extent such changes were influenced by climatic conditions and variations. As these changes have only been observed in the past three to four years, the farmers suspect that the changes may be part of a cyclic event that could return to normal sometimes soon (Gordon, *pers. com.*).

The findings from the study carried out by the CBDAMPIC project involving the communities of Lateu, Luli and Panita as well as the Vulnerability Assessment of islands in the Torres, Tafea and Shepherd Groups highlighted the impacts of climate change on water supply, agricultural activities and health of these communities (see Table 6). Salt spray, water shortages due to prolonged dry spells, flooding and contamination of ground wells, and erosion of the foreshores are having a serious impact on the safety and health of these communities and these problems are likely to get worse as temperature and sea level rises. The seriousness of these problems has already caused a number of communities to abandon their villages to resettle elsewhere. This scenario is likely to happen again in other low-lying areas of Vanuatu as the government and rural communities have limited capacity to deal with these kinds of situations.

LIVESTOCK

It is predicted that increased carbon dioxide concentrations in the atmosphere and warmer temperatures will be conducive to rapid growth of green matter rather than crops and this might affect seasonal food security (NACCC, 2007). Rapid growth could reduce the nutritional value of pastures which could in turn result in fewer animals supported per unit area of pasture land and this could have a detrimental effect on beef production, both for export and for local consumption.

The Ministry of Agriculture has reported an increased incidence of intestinal problems in cattle often associated with pasture. Similar problems (worm and infections) have been encountered by the piggery farmers.

The Ministry offers a limited veterinary service to farmers on Efate and Espiritu Santo only and is ill-equipped to offer much assistance during any major outbreak of animal diseases whether climate change-related or otherwise. Hot temperatures could result in the relocation of stocks to cooler climates (an adaptation measure) and this could entail significant costs to the farmers especially given the poor state of most of Vanuatu's roads. Local farmers with knowledge of which breeds or varieties can best adapt to changing conditions can provide invaluable input to any effort aimed at mitigating the negative impacts of climate change to the livestock industry.

Small scale livestock farmers will be mostly affected by increased temperatures and drought as these could cause soil compaction and dry up the streams on which the farmers depend for their primary source of water. Overstocking and overgrazing could result from dried conditions and this would in turn result in loss of animal weight and further degradation of pasture lands.

WATER MANAGEMENT

Water is vital to agriculture development and production in Vanuatu. Population growth, particularly in urban areas, is already placing pressure on water resource and supply services. Climate change is likely to increase the demand for water and yet reduce the quality and affect water sources. This will have implications for water source management and water use especially for industries and agriculture which are heavy water users.

Vanuatu has limited surface water and villagers on many islands and residents of both urban areas (Port Vila and Luganville) are dependent on ground water.

Increased temperatures are likely to increase the demand for portable water, however increased heat, greater run-off from high intensity rainfall events, decreased rainfall and an associated increase in evaporation could reduce the rate of ground water recharge and decrease surface water flows. Water shortages that are already apparent in dry seasons would become more pronounced and may require more sophisticated water distribution networks to maintain human populations and agriculture production in severely affected areas.

Any increase in sea level could cause salt-water intrusion into the shallow ground water lens in coastal areas, particularly if ground water recharge was reduced or water over-extracted. Increased rainfall often associated with cyclones could also cause flash floods, soil erosion and further pollution of freshwater and marine environments. Increasing population will place additional pressure on the already stressed water supply systems and any further pressure resulting from climate change and climate variability would be extremely hard for the government and people of Vanuatu to cope with.

SOIL AND LAND MANAGEMENT

Increased rainfall could result in water-logged soils unsuitable for agriculture and other uses. It could lead to soil erosion and loss of soil nutrients important for plant growth.

Climate change could influence to the way land is managed in Vanuatu. Changes in rainfall could see the introduction of less water-demanding species and varieties or the introduction of new land management regimes that are better tailored to cope with the changing weather or rainfall patterns. Monoculture plantations may no longer be suited to the changing conditions in certain parts of the country and changes in rainfall and temperature could result in the proliferation of new or dormant pest and diseases that could cause considerable damage to agriculture crops and hence food security for the people of Vanuatu.

Agriculture crops like wild yams that used to act as soil cover against run-off is reported to be sprouting during the wet season as opposed to the past when they usually sprout before the wet season. This means that this crop has lost its soil protective function as a result of shifts in weather patterns (Brian, *pers. com.*). The promotion of multi-cropping system which are likely to increase the

resilience of agricultural crops to climatic events and prevent the spread of pests and diseases that is often associated with increased temperatures and high rainfall may be an appropriate approach to managing soil and land in response to future changes and shifts in weather patterns.

FORESTRY

The loss of forests, whether from agriculture land clearing or from climate related activities can have devastating effects for the people and economy of Vanuatu. While almost 70 percent of the country's land area remains under forest, less than 30 percent is of merchantable value. Non-forested lands are used primarily for agriculture, gardening and settlement. The rapid increase in population growth, coupled with the effects of cyclones and agriculture on the remaining land would inevitably result in the rapid decrease in total forested areas.

Most island forest species have small ranges, which in turn leaves them particularly vulnerable to land use changes because these changes can easily affect the species' entire range. (Fonseca *et al*, 2006). Clearing of forest leaves areas open for invasion by alien species that then dominate secondary forests.

Vanuatu Forestry staff reported changes in the flowering and fruiting patterns of certain forestry crops and there appears to be an increase in the incidence of pest and diseases in species such as sandalwood, white wood (caterpillar attack) and mahogany (shoot porous). Invasive species are said to be more wide spread and seed collection from major species has been particularly low compared to past years (Viji, *pers. com.*). Salt spray in certain islands of Vanuatu is causing forest dieback and the slash and burn method used for agriculture land clearing is a common threat to forest areas.

Very little is known about the likely impact of climate change on forest wildlife in Vanuatu. Birds and bats play an important role in propagating forest species and are often excellent indicators of the health of forested areas.

Reforestation plans may need to be reviewed in light of changing climatic conditions. Increased temperatures in the northern islands may require research into the use of species that are resilient to the hot weather conditions in that part of the country. Increased rainfall in the other areas of the country would likewise deserve the choice of species that can do well under the wet conditions.

FISHERIES

Vanuatu, like other Pacific island countries depend heavily on subsistence fisheries for their food security. Seafood comprises a very high percentage of the animal protein consumed by Pacific Islanders, much higher than the world average of 17 percent. If the subsistence fisheries ceased to exist, Vanuatu may have to spend US$7–$15 million a year for substitutes with similar protein content (World Bank, 2000).

The impact of long-term trends in climate change, in particular related to global warming, is less well-understood in fisheries but is beginning to receive attention (FAO, 2007a). Climate change and rising sea levels are likely to impact on marine resources through their effects on corals and reef ecosystems. Coral bleaching could increase as a result of increased temperatures and there are concerns about the possible increase in ciguatera poisoning due to increased temperatures of the oceans, marine pollution from land-based activities and sedimentation of the coastal areas and water run-off.

Changes in ocean circulation patterns, may affect fish populations and the aquatic food web as species seek conditions suitable for their lifecycle. Higher ocean acidity (resulting from carbon dioxide absorption from the atmosphere) could affect the marine environment through deficiency in calcium carbonate, affecting shelled organisms and coral reefs (ibid).

The damage to coral reefs from cyclone events can be considerable as was the case with reefs around Efate from TC Ivy in 2003. Several outbreaks of the crown of thorns have been reported since the cyclone but it is difficult to say if this was directly related to the cyclone damage.

MANGROVES

Mangroves are productive ecosystems that are important to the livelihoods of coastal communities. Many fish and other marine species breed and live in mangrove areas and yet, many such areas are being destroyed or converted to other uses.

Mangrove forests also play an essential role in protecting the coast against storms and inundation. Mangrove areas are believed to be declining in Vanuatu, even in certain isolated areas where population densities remain low. Pollution from land-based activities is perceived as the most common threat to mangrove areas although land clearing is also a threat.

Hao bae yumi ol pipol blong Vanuatu i save dil wetem *Climate Change*???

ADAPTESEN NOMO!!

Long englis oli definim **adaptesen** olsem:*"the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences."*

Long Bislama, **adaptesen** i minim: "*Ajastem wei blong yumi behave mo akt folem ol expekted climate jenjes, blong yumi save rediusim no-gud aotkam o winim samfala benefit "*

Adsaptesen: Claemen i stap jenis, so yumi tu yumi mas jenis wetem.

Kwesten: Bae yumi jenis olsem wanem?

Ansa: Long <u>Forestry</u> yu save:

- Plan tri mo bus blong kontrolem erosion long graon
- Setem ap ol konsevesen erias blong protektem samfala species we oli no strong o plante
- Planem mangrove mo narafala species long coast blong holem taet graon.
- Planem ol priority species olsem Sandalwood, Whitewood, Nangai, Natapoa, Mahogany blong kat wan narafala sos blong income.
- Selectem samfala species we oli save gro gud long niufala climate condisens
- Usum ol mixed species plantesens, no planem wan kaen hud nomo.
- Jusum ol hud we oli save strong agensem disease, pipet mo ol narafala sik.
- Planem garen insaed long plantesen blong yu, blong mekem agroforestry
- Konsevem ol tradisonal wei blong planem mo lukaotem Karen mo bus

Ansa: Long <u>Livestok</u> yu save:

- Promotem mo bridim ol animol we oli save risistem klaemet change: mixim wael animol wetem animol blong fanis.
- Usum moa ol livestock we oli adapt finis long aelan blong yu.
- Improvum kondisen blong living long ol animol, lukluk long gudfala kaikai mo shelta blong olgeta.

Ansa: Long <u>Agrikalja</u> yu save:

- Traem faenem ol crops we oli prodiusim moa kaikai, o we kaikai i strong moa.
- Traem selektem ol crops we oli save resist long climate change bitim ol narawan.
- Usum samfala techniques blong impruvum soil long garen (fertilize wetem sitsit blong buluk) or usum ol plants olsem gliricidia).
- Usu mol tradisonal food preservesen techniques, blong sevem kaikai
- Usum agroforestry
- Identifaem ol food narafala food sources sapos crops oli fail
- Muvum aot ol Karen we oli stap klosap tumas long solwora.
- Planem samfala tri blong blokem salt spray we i kam long solwota
- Lukluk long niufala fruiting mo flowa taem blong ol crops mo ajustem planting calenda blong yu.

Gavmen i putum ol following priorities blong adapt long climate change long Vanuatu:

1. Agriculture & food security (preservation/processing/marketing, modern & traditional practices, bartering)
2. More resilient crop species including traditional varieties
3. Land use planning and management (modern & traditional agricultural practices, early warning including traditional systems)
4. Water management policies/programmes (including rainwater harvesting)
5. Sustainable forestry management
6. Community based marine resource management programmes (modern & traditional/aqua-culture)
7. Mainstream climate change considerations into infrastructure design and planning (modern & traditional, EIA)
8. Sustainable Livestock farming and management
9. Develop Integrated Coastal Zone Management (ICZM) programmes, including mangroves & coastal flora management plan.
10. Sustainable tourism
11. Vector & water borne disease activities (modern & traditional)

on water resources while providing immediate benefits to areas that are already suffering from seasonal shortages of water.

~ Regulate the extraction of freshwater from coastal aquifers. The introduction of policies that allow the extraction of freshwater from coastal aquifers only where there are no feasible alternatives would reduce the vulnerability of coastal communities and reduce the need to replace infrastructure should salt water intrusion occur.

In light of the vulnerabilities identified and the adaptation options discussed above, a national strategy to mitigate and adapt to climate change is suggested in Table 5.

TABLE 5: **A NATIONAL STRATEGY TO MITIGATE AND ADAPT TO CLIMATE CHANGE**

CLIMATE CHANGE ISSUE AND VULNERABILITIES	MITIGATION STRATEGY	ADAPTATION STRATEGY
ROOT CROPS		
Declining crop production as a result of changing climatic conditions	~ Promote adaptive management approaches ~ Increase public awareness about potential impacts of climate change on agriculture and food security ~ Review breeding strategies and regulations concerning varieties release and seed distribution ~ Support agriculture research especially on traditional food crops ~ Encourage and support local processing of food crops (e.g. cassava chips and flour, coconut oil, etc.)	~ Diversify root crops ~ Select crops and cultivars that are tolerant to abiotic stresses ~ Increase support for plant breeding programme ~ Broaden genetic base of traditional food crops ~ Develop locally-adapted crops ~ Adopt agro-forestry practices ~ Promote low tillage and permanent soil cover on agriculture lands ~ Construct safe food storage facilities ~ Identify alternative food sources including imports ~ Research on farming systems including soil/land husbandry
Increased pest activities due to changes in temperature and rainfall	~ Promote adaptive management and risk-coping production systems ~ Review quarantine control measures for local distribution and propagation of food crops ~ Strengthen research capacity of Ministry of Agriculture	~ Select crops and cultivars with pest and disease resistance traits ~ Adopt agro-forestry practices ~ Identify alternative crops for specific ecologies ~ Broaden genetic base of traditional food crops ~ Identify and document pests and pest activities

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[→] Table 5 continued

CLIMATE CHANGE ISSUE AND VULNERABILITIES	MITIGATION STRATEGY	ADAPTATION STRATEGY
Salt spray and rising sea levels affecting home gardens and crops	~ Impose bans on clearing of coastal vegetation ~ Develop national land use plan ~ Develop coastal infrastructure management plans	~ Move gardens away from low-lying areas ~ Plant littoral vegetation as buffers against salt spray ~ Undertake cost-benefit analysis of various coastal protection measures ~ Identify and select suitable species for coastal rehabilitation
Shifts in weather patterns affecting planting and harvesting regimes	~ Put in place early warning and risk management systems ~ Apply adaptive management and risk-coping production systems	~ Adjust planting and harvesting timetables to prevailing conditions of past 3-4 years ~ Revive traditional food preservation techniques ~ Undertake assessment of impact of shifting weather patterns of traditional food crops ~ Crop improving programs focusing on climate change adaptation
FORESTRY		
Increased pest activities due to changes in temperature and rainfall	~ Promote adaptive management and risk-coping production systems ~ Review quarantine control measures for local distribution of tree seeds and seedlings ~ Increase research capacity of Department of Forestry	~ Select tree species with pest and disease resistance traits for plantation purposes ~ Adopt multi-cropping as against mono-cropping ~ Enhance the preservation and use of local genetic resources ~ Carry out silvicultural research on main forestry species
Loss of forests due to cyclones and wind damage	~ Reduce GHG emissions from deforestation through more effective management of forest resources ~ Review forest policy to make replanting of logged over forests a condition of logging licenses ~ Carry out feasibility studies of salvage logging of cyclone affected forests	~ Expand genetic selection to include other priority species such as *Santalum austro caledonicum (*sandalwood), *Agathis Macrophylla (*kauri), etc. ~ Select seed provenances for altered climatic conditions ~ Promote mixed species plantations ~ Carry out salvage logging in wind-damaged forest areas
Limited understanding of the impact of climate change on forests	~ Develop media and public awareness campaigns ~ Incorporate climate change science in school curriculum	~ Intensify forest assessments and monitoring and establish new tools and indicators to rate forests and species vulnerability

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[→] Table 5 continued

CLIMATE CHANGE ISSUE AND VULNERABILITIES	MITIGATION STRATEGY	ADAPTATION STRATEGY
	FISHERIES	
Increased sea temperature could affect biological properties and distribution of fish species thereby affecting fish catches and food security	~ Develop resilient and adaptive fishery management systems ~ Prepare awareness raising initiatives to help communities make appropriate decisions about their management of marine resources ~ Increase research capacity of Fisheries Division	~ Promote marine or freshwater aquaculture ~ Modify fishing effort and catches according to the state of the stocks ~ Promote alternative sources of protein and economic activities for communities during lower productivity phases ~ Promote coastal area management approaches
Increased ciguatera incidences	~ Improve public awareness and understanding about connection between climate change and ciguatera	~ Continue monitoring of incidences of ciguatera outbreaks ~ Identify and document linkages between ciguatera and climate change
Negative impacts from more frequent storm surges, decreased salinity during high intensity rainfall events and increased coastal erosion on mangroves, sea grass and other near shore ecosystems	~ Develop adaptation strategies to any reduction in harvests of marine resources including replacing fishing with alternate sources of protein ~ Impose ban on clearing of coastal vegetation	~ Promote alternative sources of protein during lower fishery productivity phase ~ Promote marine or freshwater aquaculture ~ Modify fishing effort and catches according to the state of the stocks
Limited understanding of the long term trends in climate change, especially related to global warming, in fisheries	~ Develop awareness programs based on existing knowledge targeting politicians, schools and coastal communities	~ Collect and document evidence of changes in fisheries to enable better understanding of climate change on the fishery sector
	LIVESTOCK	
Increased temperatures could affect health, productivity and reproductive efficiency of livestock	~ Consider animal husbandry changes such as ruminant diets and stocking ratios ~ Increase research capacity of Livestock Division	~ Promote animal breeds or varieties that can best resist changing conditions ~ Promote locally adapted livestock breeds
Climate variability could enhance growth of less nutritious pastures	~ Monitor fodder and pasture effects on livestock	~ Identify and support appropriate pasture management practices

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[→] Table 5 continued

CLIMATE CHANGE ISSUE AND VULNERABILITIES	MITIGATION STRATEGY	ADAPTATION STRATEGY
	WATER SUPPLY	
Variability in river flows and aquifer recharge resulting from climate change	~ Develop appropriate water management regimes ~ Encourage mulching and zero tillage in areas where there is intense rainfall ~ Develop laws to protect watershed areas ~ Awareness raising programs	~ Promote land and forest conservation techniques ~ Increase rainwater catchment and storage capacity ~ Establish appropriate water distribution facilities ~ Control issuance of logging licenses ~ Formulate land and water use policies
Increased salinity of ground water sources resulting from salt water intrusion, overuse and flooding	~ Develop water management policy especially for small islands in the group ~ Promote water and forest conservation	~ Increase rainwater catchment and storage capacity ~ Establish water distribution facility ~ Regulate use of irrigated systems
	OTHER FACTORS	
Loss of traditional farming techniques	~ Revive use of traditional farming techniques ~ Promote research on traditional food crops	~ Conduct training workshops on use of traditional farming techniques ~ Document traditional farming techniques for future use
High population growth rate	~ Promote public awareness and education campaigns to draw attention to the impact of a fast growing population on the socio-economic development of the country	~ Develop and enforce a population policy for Vanuatu ~ Introduce family planning initiatives especially in rural areas ~ Provide incentives to control family sizes
Resistance to change	~ Support public awareness raising initiatives ~ Develop incentives programme in support of change	~ Improve understanding of the need for change in accordance with changing conditions and circumstances ~ Carry out demonstrations in support of need for change
Influence of large scale, single crop farms	~ Increase support for small scale farming ~ Consider incentive scheme (e.g. subsidy) in support of small farmers ~ Support establishment of a small farmers association	~ Diversification of crops ~ Concentrate on traditional crops ~ Decentralize food crop breeding programme ~ Increase support for small farmers

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[→] Table 5 continued

CLIMATE CHANGE ISSUE AND VULNERABILITIES	MITIGATION STRATEGY	ADAPTATION STRATEGY
Loss of interest in traditional crops such as coconuts	~ Review and promote sustainable use of traditional crops ~ Support local processing of certain food crops (cassava, taro, coconut, etc.)	~ Invest in alternative economic use of traditional crops (e.g. coconut oil as an alternative to fossil fuel) ~ Improve genetic material from traditional crops ~ Improve market access for small farmers ~ Build national capacity and knowledge on plant propagation techniques and agro-forestry systems
Lack of a sustainable forest management plan	~ Support development of a national sustainable forest management plan ~ Increase research capacity of Forestry Division	~ Update existing information on the country's forest resources ~ Prepare sustainable forest management plan taking into account potential impact of climate change
Imbalance between forest utilization and reforestation	~ Support development of a sustainable forest management plan ~ Encourage agro-forestry practices	~ Set sustainable cut targets ~ Include reforestation as condition of logging licenses ~ Support replanting of fast growing high value species such as sandalwood, whitewood, etc.
Lack of capacity to service livestock industry	~ Build capacity of veterinary unit within Ministry of Agriculture	~ Expand and decentralize veterinary service ~ Offer training in animal husbandry for small farmers ~ Seek support from regional institutions such as SPC

Climate Change Science

Met Office

www.metoffice.gov.uk/education

Then

We have a good understanding of what Earth's climate was like hundreds of thousands of years ago.

By analysing tree rings, air bubbles trapped in ice cores and the chemistry of ocean sediments, scientists can obtain information about the atmosphere and past temperatures.

In recent centuries, temperature measurements using thermometers have been made from weather stations on land, from ships and ocean buoys, and more recently using satellites.

Tree rings

Long-term data on the climate are relevant not only for understanding the past and present climate, but for what is likely to happen in the future.

Studying climate requires an understanding of the chemical and physical processes in the atmosphere.

In 1896, Svante Arrhenius (1859–1927), a Swedish chemist, linked the amount of greenhouse gases in the atmosphere, such as carbon dioxide (CO_2) and Earth's temperature.

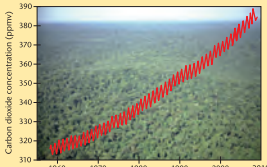
In 1938, Guy Callendar (1898–1964), a British military engineer, first suggested CO_2 levels were rising due to fossil-fuel burning.

Ice cores after drilling

Now

The science of climate change has come a long way.

In 1958, Charles Keeling began making direct measurements of CO_2 in the atmosphere in Hawaii. These data show a rapid rise in CO_2 and are used today by climate scientists across the world. Although the amount of CO_2 is different from season to season (there is less CO_2 in the air in the northern hemisphere in summer because increased vegetation growth absorbs CO_2) the annual CO_2 levels show a dramatic increase. We know the increase in CO_2 concentration is due to human activity.



Atmospheric CO_2 measured at Mauna Loa, Hawaii

Natural climate variability and change

To understand climate change, it is important to recognise the difference between weather and climate.

The weather is the state of the atmosphere around us. Temperature, rain, sunshine and wind change hour by hour and day by day. The climate is based on the average of these events over time, taking into account their variations.

The climate differs around the world — for example, some areas are hot and humid while others are cold and dry. This depends on location. In the UK, some summers are hot, others cool; some winters colder and others warmer. This happens because of natural variability in Earth's climate.

In addition to natural variability, there are patterns in the climate. Some patterns are repeated yearly while others return after thousands of years. For example, whereas seasons return yearly, ice ages occur around every 100,000 years.

Ice ages are due to changes in Earth's tilt and orbit around the Sun.

Scientists are confident that the world has not been as warm as it is now for at least 1,300 years.

This rise in temperature cannot be explained by known natural forces such as solar variations. There is strong evidence that humans are responsible.

Ice skating on the Thames at Hurley 1895

Some climate physics

There are many parts of the climate system. Here is a focus on just a few of the important physical principles that affect climate.

Thermal expansion

As water warms it expands and takes up more space. This is called thermal expansion and is an important factor affecting sea level rise.

Reflectivity

Snow and ice reflect the Sun's energy back into space, keeping Earth cooler than it would be otherwise.

A surface's reflectivity is called albedo.

Ice covers large areas of the Arctic, Antarctic and mountainous regions. As the climate warms, glaciers and ice caps around the world are melting at a rapid rate. As the ice melts, the land and ocean beneath are exposed. Because they are darker and less reflective (have a lower albedo) than ice they absorb more energy from the Sun, causing the atmosphere to warm further. This is like the difference between wearing a black jacket and a white jacket on a sunny day. We feel warmer in a dark jacket.

Displacement

When ice on the land melts it causes sea levels to rise, but when floating sea-ice melts there is no change to sea level.

This process is known as displacement or Archimedes' principle after the Greek mathematician, physicist, engineer, astronomer and philosopher who lived around 200 BC. He discovered the principles of density and buoyancy while taking a bath.

When icebergs or sea-ice melt there is almost no change in sea level, because the ice 'displaces' almost the same volume of water whether it is frozen or liquid. Try this experiment with ice cubes in a glass of water. However, when land ice melts (such as glaciers) sea level rises because more water is added to the ocean.

Just how much the sea level will rise in the future due to the melting of land ice is difficult to determine.

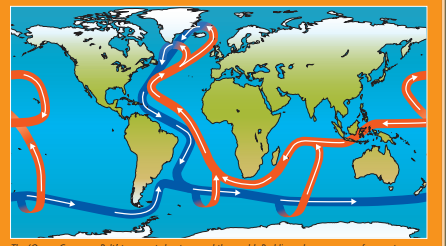
Interaction of ice and ocean

Oceans soak up and store more heat than the land and atmosphere, and so slow down the warming of the climate. The mixing of warm water currents at the sea surface and cold, deeper currents helps keep the overall temperature of Earth's atmosphere down.

These ocean currents, called the 'Ocean Conveyor Belt', transport heat around the world. At present, warm, salty water moves from the Gulf of Mexico and the Caribbean, northwards towards the UK and into the Arctic Ocean. Without this warm current, the UK would be much colder in winter.

As the warm, salty current moves north it gradually loses heat and cools to the temperature of the surrounding cold water of the Arctic. But because the current is saltier it is heavier than the surrounding water and sinks to the bottom of the ocean and then returns south as a cold current.

As Arctic glaciers melt and their freshwater flows into the salty ocean they can alter the Ocean Conveyor Belt and the climate. Freshwater is not as heavy as salty water so does not sink. This could slow down the ocean circulation and the movement of heat. Although it is thought that the circulation has stopped during past ice ages, it is unlikely that it will completely stop in the next 100 years in response to future climate change.



The 'Ocean Conveyor Belt' transports heat around the world. Red lines show warm surface water currents. Blue lines show cold deep water currents

The enhanced greenhouse effect

To understand how rising levels of CO_2 influence climate, imagine the atmosphere in terms of what happens in a greenhouse.

Energy from the Sun enters Earth's atmosphere in the form of shortwave radiation (sunlight). Where there are no clouds most of these rays pass through the atmosphere. On reaching Earth's surface they are absorbed and heat the land and sea.

As the land and sea warm they give off a different type of radiation, known as infrared. Infrared waves are invisible, longer and are absorbed by greenhouse gases in the atmosphere.
This heats the atmosphere. This natural process is known as the greenhouse effect because it is like the warming in a greenhouse. The atmosphere is similar to a blanket keeping Earth warm.

Without the greenhouse effect most of the Sun's heat would escape to space and Earth would be around 30 °C cooler than it is — too cold for most forms of life.

The main greenhouse gas responsible for recent climate change is CO_2.

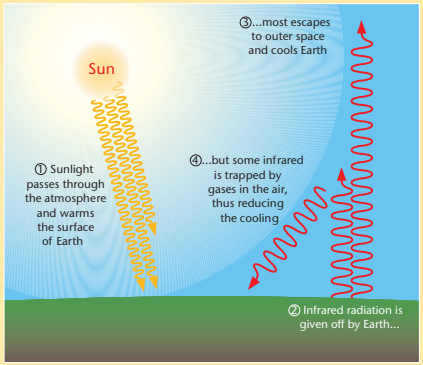
How are humans causing climate change?

For hundreds of thousands of years the amount of CO_2 in the atmosphere was much lower than it is today. Human activity has increased the amount of greenhouse gases and heat trapped in the atmosphere, enhancing the natural greenhouse effect. Scientists, politicians and the media often refer to the increase in temperature as 'global warming' or 'climate change'.

Burning fossil fuels containing carbon, like coal and oil, releases large amounts of CO_2 into the atmosphere. Cutting down forests also leads to an increase in CO_2 because trees absorb CO_2 from the air. Fewer trees mean less CO_2 will be absorbed. As trees decompose or are burnt, the carbon stored in them during photosynthesis (the process in which CO_2 is converted to plant material and oxygen) is released to the air.

The second most important greenhouse gas is methane, which is produced by bacteria that live in places like landfill sites, lakes, peat bogs and in the guts of animals like cows and sheep. Putting nitrogen fertiliser on to soils increases the amount of nitrous oxide in the air — another greenhouse gas.

High levels of greenhouse gases increase the temperature of Earth's atmosphere. CO_2 remains in the atmosphere for around 100 years before levels are reduced by being absorbed by the ocean and land vegetation. Some other greenhouse gases stay far longer. Because these gases stay around so long, reducing man-made emissions now will not be enough to stop climate change in the short-term, but will help to stabilise climate in the long-term.



The greenhouse effect

Burning fossil fuels releases CO_2

Cutting down forests increases levels of CO_2

Landfill sites and cattle generate methane

Predicting future climate

Predicting the future climate is important. We know from past and present temperature measurements that the world is warming, but how do we know what temperatures to expect in the future?

Scientists have a good idea of what influences the climate — the Sun, volcanic activity, greenhouse gases, small particles in the air (aerosols), clouds, ice, vegetation, land and the ocean. All these influences make up what is known as the climate system.

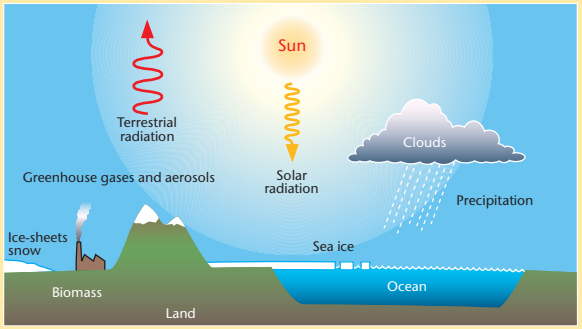
By considering all these factors, climate scientists can make predictions about climate change, enabling people, businesses and governments to make decisions about adapting as the climate changes.

Clouds

Clouds are a complex part of the climate system. They cool the planet down by shading Earth's surface from the Sun during the day. In contrast, they also insulate it by trapping heat that is trying to escape back into space, during both day and night. A warmer atmosphere evaporates more moisture from the ocean and land and some of this water vapour will turn into clouds. High clouds tend to warm the planet, while low ones cool it down. Climate scientists are currently looking at how changes to clouds will affect the future climate.

Maths and computing

To study climate change more closely, scientists have developed mathematical models of each part of the climate system and their interactions. Details of the chemical and physical processes are fed into powerful supercomputers that do billions of calculations every second.



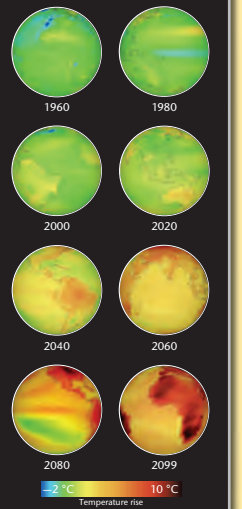
The climate system

What if?

Predicting the future climate is complex and involves asking 'what if?'
For example, what will happen to the world's temperature if we continue to increase greenhouse gases? It is essential to have an idea of how things are likely to change in each country and region to prepare for the impacts on our lives and environment.

Climate scientists use different stories about the future known as scenarios (low, medium and high risk) to estimate how the climate might change.

The further into the future you look, the greater uncertainty there is. By 2080, the rise in UK temperature could be 2 °C or as much as 5 °C as we don't know how much greenhouse gas will be in the atmosphere. That depends on things like population levels and new technologies to reduce carbon emissions. Although there are uncertainties in predictions, computer models provide the best method for predicting future climate. They also provide the best information as a basis for our response to climate change.



Global average temperature rise — high risk scenario