INTERNATIONAL SAVANNA FIRE MANAGEMENT INITIATIVE

THE GLOBAL POTENTIAL OF INDIGENOUS FIRE MANAGEMENT

FINDINGS OF THE REGIONAL FEASIBILITY ASSESSMENTS

Photos: Activities of the UNU International Savanna Fire Management Initiative & Partners in Australia, Africa, Latin America and Asia

Cover & Closing Page Photo Courtesy Warddeken Land Management: Ray Nadjamerrek Demonstrates Fire Management in West Arnhem Land, Australia.

Acknowledgements

Prepared by the United Nations University with contributions from Rick Anderson (Latin America), Robin Beatty (Africa, Introductory Materials, Australian Experience), Jeremy Russell-Smith (Asia, SFiM Preconditions) and Guido van der Werf (Global Savanna Fire Emissions).

The United Nations University wishes to thank the many people and organisations whose contributions made the International Savanna Fire Management Initiative possible, including: all those in Africa, Asia, Australia and Latin America who contributed to the Initiative's workshops and events.

Particular thanks are due to the Initiative's Advisory Committee:

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Special thanks also to

Aboriginal Carbon Fund, Shaun Ansell, Australian Government Department of the Environment, Australian Government Department of Foreign Affairs and Trade, Grace Balawag, Kabir Bavikatte, Bibiana Bilbao, Andrew Botelle, Philipp Buss, Oleg Butuzov, Charles Darwin University, The Christensen Fund, Clean Energy Regulator, ConocoPhillips, Andrew Campbell, CIS Timor, Peter Cook, Abilio Da Fonseca, Raymond De Chavez, Eileen De Ravin, Elisa De Wit, Jeremy Dore, Margaux Dumonteil, FAO, Rodrigo Falleiro, Rohan Fisher, the Rangers of the Fish River Fire Project, Rowan Foley, Ford Foundation, Summer Fueta, Nigel Gellar, Melissa George, Emily Gerrard, Lee Godden, Johann Goldammer, Cissy Gore-Birch, GIZ, Ari Gorring, Polly Grace, Leigh Gregory, Tony Gross, Terence Hay-Edie, Sarah Hobgen, Anja Hoffmann, Nolan Hunter, Indigenous Land Corporation, Indigenous Peoples' Global Partnership on Climate Change, Forests and Sustainable Development, Indonesian National Carbon Accounting System, IRDNC Namibia, Steve Larkin, Margaret Jacobsohn, Glenn James, Damon Jones, Rose Jubber, the community of Kabulwarnamyo, John Kasaona, Eugenia Kelly, Kimberley Land Council, Haruni Krisnawati, Geoff Lipsett-Moore, Jannah Lott, Lorrae MacArthur, MacArthur Foundation, Simon Mayes, Charles McNeill, Melbourne University, Mick Meyer, Gordon and Betty Moore Foundation, Bronwyn Myers, Douglas Nakashima, The Nature Conservancy, Natural Justice, Rahera Noa, Northern Territory Government, Norton Rose, Karine Nulimba, Hindou Oumarou Ibrahim, Garth Owen-Smith, Alejandra Pero, Emma Pethybridge, Ameyali Ramos Castillo, Jakob Rhyner, Jennifer Rubis, David Shelmerdine, Tebtebba, Maureen Tehan, Cath Traynor, UNDP, UNESCO, Universitas Nusa Cendana Indonesia, UNU-EHS, US National Science Foundation, Georgia Vallance, Nerissa Walton, Yvonne Walz, Warddeken Land Management, Peter Whitehead, Citt Williams, Mary-Anne Wilson, WIN-NET, Sean Wood, Dean Yibarbuk, Peter Yu.

Supported by the Australian Government

Australian Aid

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Acronyms and Abbreviations

A/R – Afforestation/Reforestation

ACCUs – Australian Carbon Credit Units

ADP – UNFCCC Ad Hoc Working Group on the Durban Platform for Enhanced Action

AFD – Agence Française de Développement

AFOLU – Agricultural, Forests and Land Use Sector

ARB – Air Resources Board, California

BEF – Burning Efficiency Factor

BioCF – World Bank's BioCarbon Fund

C – Carbon

CAR – Rural Environmental Registration System

CAR – Climate Action Reserve

CCB – Climate, Community and Biodiversity Standards

CCBA – Climate, Community and Biodiversity Alliance

CCBS – Climate, Community and Biodiversity Standards

CDEP – Community Development Employment Projects Scheme

CDM – Clean Development Mechanism

CER – Clean Energy Regulator Australia

CERs – Certified Emissions Reductions

CFI – Australian Carbon Farming Initiative

CH_4 – Methane

CIMAM – Key Fire Management Interagency Committee/Group

CIPRA – Independent Company of Military Police for Transport and Environment

CO_2 – Carbon Dioxide

COP – Conference of the Parties

CSR – Corporate Social Responsibility

CTX – Carbon Trade Exchange

CWD – Coarse Woody Debris

DBH – Diameter at Breast Height

DEMA – State Bureau of Crimes against the Environment

DFAT – Australian Government Department of Foreign Affairs and Trade

DFID – UK Department for International Development

DRC – Democratic Republic of the Congo

EAOP – Early Action Offset Programmes California

EDS – Early Dry Season

EF – Emission Factor

ERF – Emissions Reductions Fund

EROS– Earth Resources Observation and Science Centre

FAO – Food and Agriculture Organisation of the United Nations

FC – Fuel Class

FCPF – Forest Carbon Partnership Facility Carbon Fund

FL – Fuel Load

FP – Fuel Pyrolised

FUNAI – Brazilian National Indian Foundation

FVA – Framework for Various Approaches

GCF – Green Climate Fund

GEF – Global Environment Facility

GFED – Global Fire Emissions Database

GHG – Greenhouse Gas

GIS – Geographic Information System

GIZ – Deutsche Gesellschaft fuer Internationale Zusammenarbeit, German aid agency

GtCO2eq – Giga tons of carbon dioxide equivalent

IBAMA – Brazilian Institute of Environment and Renewable Natural Resources

ICMBio – Chico Mendes Institute for Biodiversity Brazil

ICMS – Ecológico – Brazilian Ecological Tax System

IFM – Improved Forest Management

IKI – German International Climate Initiative

INDCs – Intended Nationally Determined Contributions

INPE – Brazilian National Institute for Space Research

IPCC – Intergovernmental Panel on Climate Change

IPs – Indigenous Peoples

ISFL – BioCarbon Fund Initiative for Sustainable Forest Landscapes

ITCZ – Inter-Tropical Convergence Zone

JCM – Joint Crediting Mechanism

JICA – Japan International Cooperation Agency

KAZA – Kavango Zambezi Sub-Region

KfW – Kreditanstalt für Wiederaufbau, German Development Bank

KLC – Kimberley Land Council, Western Australia

LDS – Late Dry Season

LNG – Liquefied Natural Gas

LPAA – Lima-Paris Action Agenda

LULUCF – Land Use and Land Use Change and Forestry

MCD – Mpingo Conservation & Development Initiative Tanzania

MODIS – Moderate-resolution Imaging Spectroradiometer

MtCO2e – Million metric tons of carbon dioxide equivalent

N – Nitrogen

N_2O – Nitrous Oxide

NAMAs – Nationally Appropriate Mitigation Actions

NATURATINS – Tocantins Nature Institute Brazil

NAZCA – Non-State Actor Zone for Climate Action

NCOS – National Carbon Offset Standard (Australia)

NGGI – National Greenhouse Gas Inventory

NMA – Non-Market Approaches

NMM –New Market Mechanism

NORAD – Norwegian Agency for Development Cooperation

NTG – Northern Territory Government Australia

NTT – Nusa Tenggara Timur Indonesia

ODA – Official Development Assistance

OPR – Offset Project Registries California

P – Fire Patchiness

PA – Protected Area

PACT – Belize Protected Areas Conservation Trust

PDRIS – Regional Integrated Sustainable Development Project

PGAM – The State of Tocantins Programme for Environmental Management Brazil

PMR – World Bank Partnership for Market Readiness

PREVFOGO – Centre for Prevention and Control of Forest Fires Brazil

REDD+ – Reducing Emissions from Deforestation and Forest Degradation

RURALTINS – Rural Development Institute of Tocantins Brazil

SBFWG – Southern Belize Fire Working Group

SBSTTA – Subsidiary Body for Scientific and Technological Advice

SEA – South East Asia

SEMADES – Department of Environment and Sustainable Development of the State of Tocantins Brazil

SEPLAN – Department of Planning and Modernization of Public Management

SFiM – Savanna Fire Management

SIDA – Swedish International Development Cooperation Agency

SisFOGO – Brazilian National Fire Information System

SOM – Soil Organic Matter

TA – Traditional Authority

tCO2e – Tonnes of carbon dioxide equivalent

TFCA – Transfrontier Conservation Area

TFK – Traditional Fire Knowledge

TFM – Traditional Fire Management

TIDE – Toledo Institute for Development and Environment Belize

TK – Traditional Knowledge

TL – Democratic Republic of Timor Leste

UN-REDD – United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries

UNFCCC – United Nations Framework Convention on Climate Change

USAID – United States Agency for International Development

VCM – Voluntary Carbon Market

VCS – Verified Carbon Standard

PART I – EXECUTIVE SUMMARY

For thousands of years, Indigenous peoples in Australia and around the world have used fire as a land management tool.

Such use of fire by Indigenous and local communities has often been interrupted. These interruptions to traditional management have resulted in high-intensity fire regimes and correspondingly high greenhouse gas (GHG) emissions from savanna wildfires.

Recent experience in remote north Australia demonstrates that strategic reintroduction of traditional, Early Dry Season (EDS) fire management practices can reduce emissions by more than a third. When coupled with carbon market participation, or through other funding sources, this reduction also provides meaningful income opportunities for remote Indigenous communities. Savanna Fire Management (SFiM) projects also have notable co-benefits such as improving biodiversity, reinvigorating cultural ties to country, improving food security and health, enhancing human capital, and helping remote communities adapt to climate change.

Savannas support about 10% of the human population, occupy one-sixth of the land surface and, while rates of land use change are uncertain, are likely to suffer twice the rate of conversion as for tropical forests. During the 1997-2014 period, net emissions of Carbon Dioxide (CO_2), Nitrous Oxide (N_2O) and Methane (CH_4) from fires in savanna amounted to approximately 0.31 Gt CO_2-eq per year. Savanna fire emissions are predominantly sourced from Africa, contributing approximately 71% of all savanna CO_2 emissions, followed by South America (12%), Australia (7.3%) and South East and Equatorial Asia (5.9%). Other regions - including Central America, temperate North America, Boreal Asia, Europe and Central Asia - also make small contributions to the total emissions from savanna landscapes.

'Savanna burning' is an accountable activity under the provisions of the Kyoto Protocol. Australia is the only developed economy that accounts for emissions from the burning of tropical savanna in its national accounts. SFiM in tropical north Australia savanna is covered by approved methods under Australia's Emissions Reduction Fund (ERF). Under these savanna fire management methods, prescribed burns are conducted early in the dry season, lowering the intensity and extent of Late Dry Season (LDS) fires, and reducing total biomass burnt. The methodologies build upon early work undertaken by Traditional Owners in Australia in projects such as the West Arnhem Land Fire Abatement (WALFA) Project and the Fish River Fire Project. As of October 2015, there were 14 Indigenous-led fire management projects across the north of Australia.

Guided by the success of northern Australia's SFiM emissions abatement programmes, the Australian Government funded the United Nations University's Traditional Knowledge Initiative (UNU-TKI) to manage a two-year 'International Savanna Fire Management Initiative' that has assessed the interest in and feasibility of establishing similar initiatives in developing countries. In order to achieve this, regional feasibility assessments were undertaken in three separate regions of the world that contain notable tracts of tropical savanna – namely Africa, Latin America, and Asia. The purpose of the assessments was to provide communities, governments, experts and potential donors with an informed starting point to explore the potential for implementing SFiM in their region. Proposals for SFiM implementation activities in promising savanna sub-regions were also developed.

In summary, the Initiative found:

- In each assessed region, fire has been used over long periods by Indigenous and local communities for social, cultural and environmental purposes. With nterruptions to such traditional practices, LDS burning is contributing to increased GHG emissions and undermining biodiversity. The reintroduction of SFiM could bring significant environmental, social and economic benefits in all regions assessed.
- The regions assessed vary in the extent to which there is current scientific, technological, and regulatory readiness for the reintroduction of SFiM. Consequently, the type of support needed and the pathways for the reintroduction of practical SFiM in each region will be highly context dependent. Specifically:-
  - The development and application of SFiM methodologies similar to those utilised in the Australian context is likely to be possible in parts of Africa, where landscapes most resemble Australian conditions. Given that African savannas contribute 71% of global savanna greenhouse gas emissions - combined with acute human needs, reliance by local peoples on fire management to support existing livelihoods, and limited alternative opportunities – methodology-based SFiM represents an important, promising and unique opportunity for the African savanna region.
  - One of the most promising regions for SFiM in Africa is the Southern African savanna region, including the Kavango-Zambezi (KAZA) sub-region that includes parts of Angola, Botswana, Namibia, Zambia and Zimbabwe, and the Luangwa Valley sub-region of Zambia. Proposals for SFiM implementation activities have been developed for the KAZA sub-region, and the area in and around the Bwabwata National Park in North East Namibia.
  - In Latin America, savanna environments are varied and diverse, as are the social and governance contexts in which the savanna sub-regions are found. Despite long histories of fire management by the region's Indigenous peoples, fire policy has largely focused on prohibition and suppression. Some programmes have been introduced in the region to encourage and introduce strategic fire management. These programmes have built some technological readiness and human capacity for SFiM in the region. As in the case of Africa, while the application of SFiM methods similar to those utilised in

the Australian context is likely to be possible in parts of the region, further work on the ground will be required to facilitate their introduction.

  - Particularly promising sub-regions for SFiM in Latin America include the Cerrado of Brazil, the Gran Sabana of Venezuela, and the Pine Savannas of Belize. Proposals for SFiM implementation activities have been developed for each of these sub-regions.
  - In Asia, while savanna ecosystems share many characteristics with tropical north Australia, the population density, highly fragmented landscapes and high historical rates of conversion of savanna suggest that different models for the reintroduction of SFiM may be more appropriate, notwithstanding the very significant benefits that improved fire management could bring to the region.
  - Sub-regions suitable for further SFiM activities in Asia include the sub-region encompassing Eastern Indonesia and Timor Leste. A proposal for SFiM implementation activities that adopts a cross-border thematic approach based on risk management has been developed for that sub-region.

- Assuming the Australian project experience could be replicated in other regions, annual emission reduction potential from reducing CH_4 and N_2O emissions could be expected to be in the vicinity of 0.1 to 0.15 Gt CO_2 -eq per year. This potential is, however, dependant on further research and analysis of different vegetation types and different climatic conditions as compared to Australia.
- While there are many practical challenges ahead, the steps required to build readiness for SFiM are considered to be concrete and achievable over appropriate time scales and with well-targeted human, scientific, regulatory and economic investment.
- In considering future prospects for SFiM projects in developing countries, finding potential investors and understanding the demand for carbon credits, offsets and ecosystem services, is a priority and challenge of every SFiM project.
- The demand and price for SFiM projects and their credits is very diverse.
- The most promising demand for SFiM credits is from companies directly.
- REDD+ also provides some interesting opportunities for SFiM Projects.
- Long term demand and stability for the market will be driven by the timing and ambition of future climate policies, the importance of markets in delivering these targets, and the ability to implement the relevant policies (regarding supply and demand) effectively.
- The volatile and varying nature of demand further emphasises the importance of seed funding for new SFiM projects to assist them to develop viable SFiM projects. None of the various

communities and governments that the Initiative worked with have the resources to develop viable proposals for SFiM projects without some seed funding.

- Practical steps to help SFiM projects promote demand and access markets would include:-
  - Regular exchanges between SFiM projects to allow for market intelligence to be exchanged and to address the asymmetry in capacities between the suppliers and buyers.
  - Developing an international methodology through, for example, the Verified Carbon Standard (VCS) or Gold Standard (GS), to enhance and promote demand for SFiM credits.
  - Supporting efforts to link carbon markets and allow the use of international credits thereby allowing SFiM projects in developing countries to access carbon markets in developed countries.
  - Promoting Emissions Reduction Fund type developments in national carbon markets.
  - Exploring innovative market solutions, and facilitating/brokering partnerships between producers and the private sector.
  - Developing models that value and price associated co-benefits.
  - Supporting efforts to raise awareness among donors.
  - Undertaking an expert analysis of the bond market.
  - Developing an international platform or registry for SFiM projects, within one of the existing registries.
  - Establishing significant and long-term leadership by governments to support the development of an SFiM network.

PART II – INTRODUCTION

For thousands of years, Indigenous peoples in Australia and around the world have used fire as a land management tool.

Such use of fire by Indigenous peoples and local communities has often been interrupted. This has frequently followed the removal and other movements of people away from their traditional lands after colonisation, alongside government policies that prohibit the lighting of fires. This interruption to traditional management has frequently resulted in high-intensity fire regimes and correspondingly high greenhouse gas (GHG) emissions from savannas.

There is now scientific recognition of the importance of fire as a management tool in fire-dependent landscapes. Recent experience in remote north Australia demonstrates that strategic reintroduction of traditional, Early Dry Season (EDS) fire management practices can reduce the amount of biomass burnt by savanna fires and reduce emissions. When coupled with carbon market participation, or through other funding sources, this reduction can also provide meaningful income opportunities for remote indigenous communities. Savanna Fire Management (SFiM) projects have notable co-benefits such as improving biodiversity, reinvigorating cultural ties to country, improving food security and health, enhancing human capital, and helping remote communities adapt to climate change.

SFiM in tropical north Australian savannas is an approved offsets methodology under the Australian Government's Emissions Reduction Fund (ERF). Under the methodology, prescribed burns are conducted early in the dry season, lowering the intensity and extent of Late Dry Season (LDS) fires, and reducing total biomass burnt. The methodologies build upon early work undertaken by traditional owners in Australia in projects such as the West Arnhem Land Fire Abatement (WALFA) Project and the Fish River Fire Project. As of October 2015, there were 14 indigenous-led fire projects across the north of Australia (Aboriginal Carbon Fund 2015).

Guided by the success of northern Australia's Savanna Fire Management (SFiM) emissions abatement programmes, the Australian Government funded the United Nations University's Traditional Knowledge Initiative (UNU-TKI) to manage a two-year 'International Savanna Fire Management Initiative' that, among other objectives, would assess the interest in, and feasibility of, establishing similar initiatives in developing countries. The Initiative was based on the premise that as savannas cover approximately one-sixth of the global land surface, the conditions required to establish SFiM abatement programmes are unlikely to be unique to Australia.

In order to test this premise, regional feasibility assessments were undertaken in three separate regions of the world that contain notable tracts of tropical savanna – namely Africa, Latin America, and Asia. The purpose of the assessments was to provide communities, governments, experts and potential donors with an informed starting point to explore the potential for implementing SFiM in their region.

The assessments describe climate, ecosystem, biodiversity characteristics and fire regimes, and make broad recommendations as to whether SFiM would be theoretically possible in each region. They also examine general contextual factors that would indicate the interest in and readiness of different countries to implement SFiM. Where appropriate, the assessments recommend sites with high potential for the implementation of pilot projects that, while drawing from the Australian SFiM experience, would be tailored to local context.

Further analysis at the global level explores the global mitigation potential of SFiM. Also explored are various funding models for supporting SFiM. In the context of carbon markets, the demand side dynamics associated with savanna burning are also explored, in order to provide insight into future prospects for SFiM projects.

This report sets out the findings of those regional and global assessments, with further supporting information on the future prospects for SFiM globally.

The assessments were undertaken by expert scientific consultants in each region. Depending on the information available and the specific regional context, the assessments were to include:

- A broad assessment of the potential applicability of methodology-based savanna fire management in the region as a whole, with reference to climatic, ecosystem and biodiversity characteristics, and concluding with recommendations as to whether the application of methodology-based savanna fire management is theoretically possible in the region; and,
- A detailed assessment of the potential applicability of methodology-based savanna fire management in promising sub-regions, as indicated by the broad regional assessment, and an indication of promising site areas. This included describing, as appropriate given the information baseline in the region:
    - relevant vegetation, climate and fire history data and maps, and identification of gaps and the potential to obtain and/or develop relevant data;
    - the relationship of fire and biodiversity in the sub-region;
    - traditional fire management knowledge, practice and changes in fire regimes;
    - existing infrastructure and expertise for the monitoring of fire;
    - mitigation potential, sustainable development and environmental co-benefits;
    - regulatory and land-tenure arrangements;
    - the political and economic environment;
    - institutional and resource capacity; and,

- o regional demand (community interest and government support) and technical capacity needs.

In addressing each of these issues, the assessments considered a set of SFiM pre-conditions that experts involved with the Australian projects had suggested would be necessary for adapting the Australian experience to suit other regions. These are described in Part V of this report. This set of pre-conditions should be used as context for interpreting the regional feasibility assessments that follow.

In addition, to the extent possible and as appropriate (depending on the conclusions of the broad regional and detailed sub-regional assessments), detailed site pre-feasibility assessments for up to two promising sites in each region were conducted. The intention was that these could be used as the basis of proposals to potential donors for implementing practical SFiM activities in those site areas. The sites were selected after considering the complete range of SFiM preconditions.

The proposals, available separately, are indicative proposals, designed only to broadly illustrate the necessary steps and resourcing needs required for implementing SFiM in a given region. The further progression of these proposals would require discussion with participating communities, governments, scientists and donors. In addition, the inclusion of these proposals is in no way intended to preclude others from developing proposals for the same or other regional sites.

The results of these assessments are described in Parts VII - IX. They are prefaced by a summary of global savanna fire emissions and the SFiM methodologies and project experiences emerging from the Australian experience and from other contexts. This is followed by a summary and discussion of the main conclusions emerging from the assessments. The report is then concluded with a broad discussion of future prospects for SFiM globally.

PART III – GLOBAL SAVANNA FIRE EMISSIONS

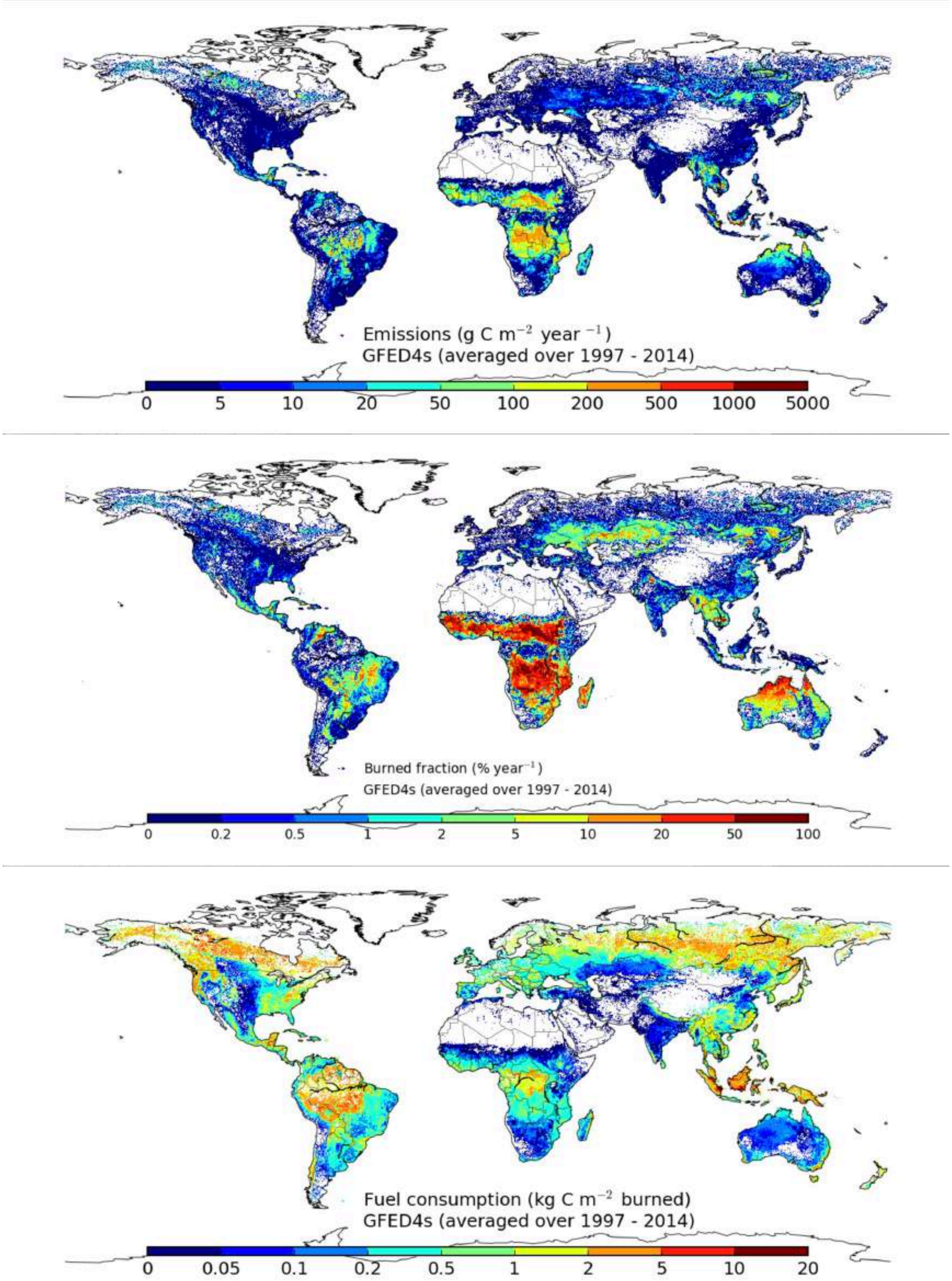
The most complete and current source of data on global fire emissions is the Global Fire Emissions Database version 4 (GFED). The GFED utilises satellite data about vegetation characteristics and productivity to estimate fuel loads, and combines this with satellite derived burned area data to estimate fire emissions. GFED is funded by NASA and the European Research Council, and is based at the Vrije Universiteit (VU) in Amsterdam. GFED4 is a revised version based on GFED3 (van der Werf *et al.,* 2010) but is now driven by improved burned area estimates (Giglio *et al.,* 2013; Randerson *et al.,* 2012) and better constrained fuel loads (Van Leeuwen *et al.,* 2014).

Another source of emissions data on savanna burning is contained in an analysis completed by the FAO statistics division (FAO, 2014). While also useful, this FAO report considers savanna burning emissions in the context of emissions from the Agriculture, Forestry and Other Land Use (AFOLU) sector. As it uses aggregated data and a slightly older data set, it is less useful for the purposes of establishing and comparing savanna emissions across regions as compared to the GFED4 data.

Based on the most recent GFED4 figures, between 1997 and 2014, gross emissions from fires globally were approximately 8 Gt CO_2-eq per year, with net emissions approximately 2 Gt CO_2-eq per year (GFED4). The difference between the gross and net emissions is due to CO_2 emissions from most fires being balanced by regrowth over longer time scales. However methane (CH_4) and nitrous oxide (N_2O) emissions remain in the atmosphere for far longer periods, contributing to net emissions from fire. During the 1997-2014 period, CH_4 and N_2O accounted for 0.7 Gt CO_2-eq. of the net emissions from fire per year. This was addition to CO_2 emissions from certain sources, such as deforestation and tropical peatlands, that were a net source of 1.3 Gt CO_2-eq per year (GFED4).

The GFED4 figures below illustrate mean annual fire emissions, fuel consumption and burned fraction in the 1997-2014 period globally.

Figure 1. GFED4 mean annual fire emissions, fuel consumption and burned fraction in the 1997-2014 period globally.



Savannas, defined as tropical and sub-tropical grasslands with varying densities of tree cover, are the most fire-prone vegetation on earth. They support approximately 10 % of the human population and occupy one-sixth of the land surface. While rates of land use change are uncertain, savannas are likely to suffer twice the rate of conversion as for tropical forests (White *et al.,* 2000; Grace *et al.,* 2006). By comparison with tropical forests, savannas store about 15% (versus. 25%) of the total carbon contained in the world's vegetation and soil organic matter, and account for a similar proportion, approximately 30%, of terrestrial net primary productivity (Grace et al. 2006). The lower storage capacity of savannas is largely due to the vegetation composition combined with the effects of frequent fires returning carbon to the atmosphere.

Annual burning from savanna vegetation is a major source of GHG emissions (FAO, 2014, Levine *et al.,* 1995; Achard *et al.,* 2004). Savanna burning releases methane (CH_4,) nitrous oxide (N_2O), and carbon dioxide (CO_2). The quantity of CH_4 and N_2O emitted depends on the quantity, type and condition of the vegetation burnt.

During the 1997-2014 period, emissions of CO_2, N_2O and CH_4 from savanna fires amounted to approximately 5.25 Gt CO_2-eq per year (GFED4). In this discussion the term 'savanna' is taken to encompass grassland, savanna and shrubland, as per the GFED4 classification. This represents approximately 65% of total global fire emissions annually. While the CO_2 emissions from savanna fires, as stated, are largely balanced by regrowth, net savanna CH_4 emissions in the same period accounted annually for 0.14 Gt CO_2-eq per year, and N_2O emissions of 0.17 Gt CO_2-eq per year. Together, these emissions accounted for a combined figure of 0.31 Gt CO_2-eq per year. This corresponds to approximately 60% of N_2O and 35% of global CH_4 emissions from fire sources annually.

Savanna fire emissions are predominantly sourced from Africa, which contributed approximately 71% of all savanna CO_2 emissions in the 1997-2014 period. This was followed by South America (12%), Australia (7.3%) and South East and Equatorial Asia (5.9%). Other regions - including Central America, temperate North America, Boreal Asia, Europe and Central Asia - also make small contributions to the total emissions from savanna. (GFED4).

As described further under the discussion of the Australian experience in Part IV below, 'savanna burning' is an activity accountable under the provisions of the Kyoto Protocol. Australia is the only developed economy that accounts for emissions from the burning of tropical savanna in its national accounts. Australia's National Greenhouse Gas Inventory (NGGI) currently accounts for GHG emissions from savanna burning specifically for the long-lived chemical species, methane (CH_4) and nitrous oxide (N_2O).

Recent fire management project experience in Australia's north demonstrates emissions savings of more than one third through methodology-compliant SFiM relative to the project baseline period (Russell Smith *et al.,* 2013). Assuming Australian project experience can be replicated in these other regions contributing to global savanna emissions, and that methodologies equivalent to those used in Australia are available and applied, then the annual emission reductions potential from reducing CH_4 and N_2O emissions could be expected to be in the vicinity of 0.1 to 0.15 Gt CO_2-eq per year. This potential is, however, dependant on further research and analysis of different vegetation types and different climatic conditions as compared to Australia. Detailed measurement, reporting and verification systems would also be required to more accurately measure the estimated potential. It may also be possible to achieve mitigation through SFiM from the increased biosequestration of CO_2. The magnitude of this potential, however, is as yet unclear and dependent on the development and testing of sequestration focused methodologies in Australia and for overseas conditions.

PART IV – THE AUSTRALIAN EXPERIENCE

The following description of methodology-based fire management and the Australian SFiM experience provides context for the findings of the regional feasibility assessments that follow.

Methodology-Based Fire Management

The savannas of northern Australia occupy 1.9 M km^2 and occur mostly under markedly seasonal monsoonal rainfall conditions, generally receiving an average of >500 mm rainfall annually.

The sparse population, limited infrastructure and low economic base in regional settings has resulted today in fire regimes being unmanaged, and characterised by the frequent (annual-biennial) recurrence of large (>1000 km^2) wildfires predominantly occurring late in the dry season. An average of ~20% of Australia's savanna region is burnt each year (Russell-Smith *et al.* 2007), with fire frequencies exceeding 50% each year in extensive higher rainfall regions (Felderhof and Gillieson, 2006; Russell-Smith, *et al.* 2009b).

Over the past decade, considerable effort has been given to developing savanna fire management projects in northern Australia. These have combined customary indigenous (Aboriginal) approaches to landscape-scale fire management with the development of scientifically robust GHG emissions accounting methodologies.

Australian Methodology-Based Savanna Fire Management

'Savanna burning' is an activity accountable under the provisions of the Kyoto Protocol, with non-CO_2 emissions reported in the Agriculture sector. Such emissions are included in Annex A of the Kyoto Protocol and count towards targets (Kyoto Protocol, 1997, Annex A). Australia's NGGI currently accounts for GHG emissions from savanna burning specifically for the long-lived chemical species, methane (CH_4) and nitrous oxide (N_2O). Australia is the only developed country economy that accounts for emissions from this source in its national accounts. It should be noted that while New Zealand reports some emissions under 'savanna burning', this includes only the burning of temperate grasslands – a different scenario as compared to the burning of tropical savanna that is the subject of this report.

Emissions and removals of CO_2 associated with savanna burning are, in contrast, reported in the Land Use, Land Use Change and Forestry (LULUCF) sector under forest land and grassland. Under the Kyoto Protocol, Parties are to report emissions by sources and removals by sinks of CO_2 and other greenhouse gases resulting from LULUCF activities under Article 3.3, covering afforestation, reforestation and deforestation that occurred since 1990. They are also to report human-induced activities they have elected to report under Article 3.4 that may include, among other activities, grazing land management (Kyoto Protocol, 1997). For the second commitment period, Australia has elected to report on grazing land management, with CO_2 emissions/removals from savanna burning therefore to be reported on during this period.

In this context, note that in savanna, emissions of CO_2 in one burning season are largely negated by vegetation growth in subsequent growing seasons. Indeed, IPCC Guidelines (2006) state that equivalency of CO_2 emission/removals within the year can be assumed for grasslands. However, where woody vegetation is burned, higher tiers should be used. Australia applies a country specific tier 2 method to estimate and report CO_2 emissions/removals from course woody debris, while emissions/removals of CO_2 from the grass and fine litter fuels is assumed to be in equilibrium.

An essential premise underlying Australia's recently developed savanna fire management methodologies is that reductions in fire frequency and intensity result in reduced GHG emissions because more of the fuel biomass (mostly grass and leaf-litter) is decomposed biologically through pathways that, compared with savanna fires, produce lower relevant emissions per unit biomass consumed (Cook and Meyer, 2009; Meyer *et al.,* 2012; Russell-Smith *et al.,* 2009). In unburnt north Australian savannas, emissions of CH_4 and N_2O arising from biological decomposition pathways are likely to be less than 10 % than that from fire (Cook and Meyer, 2009; Jamali *et al.,* 2011).

More important for long-term management, however, is the correlation between GHG emissions caused by fire compared to early dry season (EDA) versus late burn events. Wildfires typically occur towards the end of the dry season (Aug-Oct) when harmful climatic gases are released in greater abundance (Russell-Smith, 2009; Koronotzi, 2005; Scholes *et al.,* 1996), and when conditions are most congruent for fire's uncontrolled spread.

Regimes with fragmented fires that divide the landscape into patches of burned and unburned vegetation, characteristic of EDS burns, produce differing plant expressions across ecosystems than the larger more contiguous burns that are typical of late dry season regimes (Parr and Brockett, 1999). By creating multiple degrees of vegetation growth across the landscape, EDS burning is thought to increase biodiversity and decrease potential for large, destructive, uncontrolled fires later in the dry season (Braithwaite, 1996; Russell-Smith *et al.,* 1997; Boyd, 1999; Parr and Brockett, 1999; Laris, 2002).

The first Australian savanna burning methodology was developed by incorporating regionally-specific parameters and emission factors for northern Australian savannas receiving a long-term average of >1000 mm annual rainfall and exhibiting a distinct dry season of no less than six months. A further methodology is also now available for regions in the 600-1000mm rainfall zone and experiencing strong monsoonal climatic influences. A sequestration methodology is also under development.

Methodology-based SFiM projects calculate GHG reductions via an abatement model utilizing a pre-project baseline determined by the mean annual emission of the preceding 10 years, or 15 years in the lower rainfall zone. These projects incorporate traditional burning practices with modern fire mapping as well as updated science and technology to foster and record emissions reductions in corresponding project areas. Subsequent offsets are then transferred to credits and sold, as a sustainable funding strategy for further SFiM activities.

For rural and remote communities, this translates to notable co-benefits. These include: improving biodiversity, reinvigorating cultural ties to country, bolstering food security and health, enhancing human capital through alternate sources of income, and aiding rural communities to sustainably adapt to climate change.

Project-Scale Savanna Fire Management

Impetus for the development of nationally accredited project-scale savanna fire management accounting came from the establishment of Australia's legislated carbon offsets programme, the Carbon Farming Initiative (CFI). Credited offsets generated under the CFI were formally recognised by the Australian Government for trading in voluntary and existing international regulatory markets, and the national regulatory scheme that took effect from 1 July 2012. Following repeal of Australia's carbon pricing scheme in 2015, a reverse auction model is now used. Under this model, the proponents of savanna fire management projects, alongside other eligible project types, can compete in an auction for funding through the Emissions Reductions Fund (ERF). The Government of Australia enters into contracts with the successful bidders that guarantee the price and payments for future emissions reductions.

The approved savanna fire management accounting methodologies establish strict accounting protocols prescribing all methodological and calculation procedures, vegetation fuel type and fire mapping requirements, use of requisite parameter values, satellite imagery and acceptable data sources.

Key components of the ERF emissions avoidance accounting methods are that:

(i) registered project proponents have to provide evidence that they have legal access to manage the project area for savanna burning purposes—importantly, this does not equate to needing to own the land; and,

(ii) in each project year, carbon credits are generated against the preceding 10 -15year pre-project accountable emissions baseline, such that one credit is generated for each t. CO2-e abated with respect to that baseline.

Emissions Reduction Fund projects are able to generate credits throughout their crediting period. This period is 25 years for an ERF savanna fire management project, and was previously 7 years under the CFI (*Carbon Credits (Carbon Farming Initiative) Act 2011* (Commonwealth.) Part V).

Critical features of the Australian methodologies are that:

(i) fuel loads (grass, litter, coarse woody debris, heavy fuels, shrub components) are defined for specific vegetation fuel types, calculated with respect to fuel accumulation relationships determined from time-since-fire;

(ii) fire history is determined from satellite imagery;

(iii) emission factors for CH_4 and N_2O gases (i.e. their respective concentrations in smoke) differ between different fuel types (e.g. flaming combustion of grasses versus smouldering combustion of woody fuels), but not between early and late dry seasons (Hurst *et al.,* 1994; Meyer *et al.,* 2012); and,

(iv) fire spatial patchiness and burning efficiency factors vary significantly with fire severity, which in turn is strongly related to fire seasonality—i.e. EDS fires typically are less severe than LDS fires (Russell-Smith and Edwards, 2006).

SFiM involves carrying out a planned series of management burns early in the dry season, sometimes followed by fire suppression late in the dry season. These prescribed EDS fires are usually less intense than LDS fires, consuming less fuel and emitting less GHG. As noted, recent Australian project experience employing an EDS approach demonstrates emission savings of up to one third through methodology-compliant SFiM relative to the project baseline period (Russell Smith *et al.,* 2013). SFiM creates firebreaks and reduces available fuel loads in the landscape so that fires starting late in the dry season will emit less GHG and can be more easily contained. Management burns can be ignited from aircraft, vehicles, boats, or on foot.

SFiM is generally undertaken when there is a regular fire problem involving uncontrolled burning of large swathes of savanna on a regular cycle (1-5 years).

Australian Project Experiences

The West Arnhem Land Fire Abatement Project (WALFA) operates over 28,000 km^2 of indigenous-owned land in rugged, very remote and fire-prone high rainfall (> 1000mm) savanna in the 'Top End' of the Northern Territory. Commencing informally in 1997 as a landscape-scale fire management project at the behest of senior indigenous land owners, early objectives concerned (i) re-engaging younger and older generations with their traditional lands, (ii) building capacity of regional indigenous ranger groups to implement a coordinated and strategic landscape-scale fire management programme using both customary (detailed indigenous knowledge) and contemporary (satellite fire mapping, Geographic Information System—GIS, and aerial ignition technologies) toolkits, in order to (iii) address a severe unmanaged LDS wildfire problem, with resultant deleterious impacts on internationally significant biodiversity values (Russell-Smith *et al.,* 2009; Whitehead *et al.,* 2009).

From 2000, the WALFA scientific programme incorporated the development of a savanna burning GHG emissions accounting methodology, and associated recognition of the potential for strategic landscape fire management in the project area to reduce GHG emissions on an industrial scale. In 2005, a 17-year agreement was reached between WALFA landowners, the Northern Territory Government, and a transnational energy company, ConocoPhillips, to annually offset 100,000 t.CO2-e from the Liquefied Natural Gas (LNG) plant for a fee of AUS$1.1M per annum (indexed to 2006). Over the period 2005-2011, effective fire management in the WALFA project area delivered substantially in excess of its contracted commitment (Russell-Smith *et al.,* in press). While starting out as, essentially, a voluntary arrangement (Wunder *et al.,* 2008), under Australia's nationally regulated CFI/ERF scheme, WALFA now has the capacity to additionally operate as an accredited offset project.

With the implementation of Australia's emissions trading scheme in mid-2012, followed by the later repeal of the carbon pricing mechanism and introduction of the Emissions Reductions Fund, considerable interest developed in expanding WALFA-style savanna fire management projects in other fire-prone regions of northern Australia. Much of that interest focuses on lands owned or managed by indigenous Australians. By 2015, there were 14 Indigenous-led savanna projects across three states in the north of Australia (Aboriginal Carbon Fund, 2015).

As demonstrated by WALFA and the other Australian SFiM projects, it is eminently feasible to (i) operationally implement strategic fire management at landscape scales, and (ii) apply robust and transparent GHG emissions accounting procedures. While the multi-faceted, cross-cultural requirements for establishing effective and inclusive governance arrangements are more challenging, projects such as those mentioned above offer successful examples.

PART V – PRECONDITIONS FOR SFIM

The assessments were based around a set of SFiM pre-conditions that experts involved with the Australian projects suggested would be necessary for adaptation of that experience for application in other regions. These are described below. This set of preconditions should be used as context for interpretation of the regional feasibility assessments for Africa, Latin America and Asia that follow, as well as the associated pre-feasibility site assessments available separately. Box 1 below identifies in summary form the main pre-condition related questions that should be asked in determining readiness for methodology-based SFiM in a given region and site area.

BOX 1. SFiM CHECKLIST SUMMARY

- *Technical Questions*
  - *Is there an identified late dry season wildfire problem?*
  - *Is there an eligible vegetation and fire ecology setting?*
  - *Will population density, land use and habitat fragmentation patterns support SFiM?*
  - *Is detailed vegetation mapping available?*
  - *Is biodiversity baseline data available or are further biodiversity surveys and ecological studies required?*
  - *Are there necessary mapping products for defining the potential project area?*
    - *Adequate scale mapping (at least 1:100,000) available digitally, describing at least district / regional administration boundaries, tenure, broad vegetation classes based on robust research, land use?*
    - *Reliable / indicative fire mapping products at a monthly/seasonal time step (derived from satellite imagery at 1:250,000 [e.g. MODIS] at least) for describing and assessing contemporary fire patterns, and recent fire history from at least 2000 (coincident with start of MODIS fire mapping archive)?*
    - *Both vegetation and fire scar mapping needs to be validated, and should be available to be printed out/overlaid for community consultation purposes, ultimately to identify those areas of prospective 'natural/semi-natural' flammable vegetation which require better management.?*
  - *Has or can an SFiM emissions abatement methodology be developed?*
    - *Is baseline data available that covers both EDS and LDS fires and that covers a time period long enough given the fire frequency in the region?*
  - *Has or can an SFiM sequestration methodology be developed?*
    - *Can permanency requirements associated with sequestration requirements be met (i.e. security of land tenure and length of guaranteed fire management service delivery?*
  - *Are there tools (i.e the Savanna Burning Abatement Tool (SavBat)) for estimating the quantity of abatement generated from the project fire management?*
- *Legal and Policy Questions*
  - *Is there a supportive policy and legislative framework for SFiM?*
  - *Is there an effective national greenhouse accounting system in place?*
  - *Are issues of rights over carbon sufficiently clear?*
  - *Is land tenure sufficiently clear for methodology-based SFiM? Noting that although in many savanna settings land tenure arrangements are complex, rights to access and manage lands may*

be sufficient for fee for service annual emissions abatement activities. .

  - *Is SFiM a national priority and recognised in national plans, and strategies i.e. Nationally Appropriate Mitigation Actions (NAMAs), National Biodiversity Strategies and Action Plans (NBSAPs), national risk reduction strategies etc.?*
  - *Are there the frameworks in place such that emissions abatement/sequestration activities can be aligned to relevant national/international accounting schemes so that generated carbon abatement can be credited.*
  - *Is there a demand for offsets generated from SFiM activities sufficient, at a minimum, to cover the costs of SFiM?*
  - *Is there available funding for SFiM projects, either up to the point of covering project costs where market approaches used, or on an on-going basis in other cases?*
- *Equity and Rights Questions*
  - *Is there locally driven demand for SFiM at the community level?*
    - *Does the community recognize that there is a fire management problem?*
    - *Is implementation of savanna fire management activities culturally acceptable?*
    - *Has there been a history of fire management by the relevant communities?*
    - *Does the community perceive that savanna fire management activities may have broader economic/cultural benefits?*
  - *Can prior informed consent be demonstrated?*
  - *Has there been a broader consultation within the community to allow them to assess for themselves how a savanna fire management project might help meet other economic and cultural aspirations or compete with other economic and cultural activities?*
  - *Are there clearly defined processes, roles and responsibilities for decision-making on communal land?*
  - *Is there effective governance at the community level in place to ensure that social co-benefits are realized, such that payments are distributed equitably among the community, or otherwise used in ways that support the needs and aspirations that the communities themselves define?*
  - *If needed, has there been consideration of how to reconcile traditional governance models with those expected by donors and markets?*
  - *Is there acceptance of market-based approaches among Indigenous and local communities or is another approach preferred?*
- *Capacity Questions*
  - *Is there capacity for SFiM across government, communities, NGOs, academia and the private sector for:*
    - *Delivering project accounting and management services?*
    - *Implementing accounting procedures for emissions abatement approaches?*
    - *Delivering project legal services?*
    - *Measuring co-benefits?*
    - *Training rangers?*
    - *Surveying and monitoring emissions and biodiversity baseline and impacts?*
    - *Identifying safeguards?*
    - *Quantifying emissions?*
    - *Developing policy and legislation?*
    - *In National greenhouse accounting?*
    - *In GIS systems?*

Sections (l) – (4) below set out introductory concepts and terminology, as well as other background information to the pre-condition questions identified in Box 1. These preconditions are based on the Australian experience, with some notes on the potential relevance of those preconditions in other regions and contexts, as is more fully explored in the individual regional assessments that follow.

(1) Introductory concepts

Vegetation and fire ecology setting

- savanna conditions
    - Savannas may be defined broadly as tropical and sub-tropical grasslands with varying densities of tree cover. In tropical regions constituent grasses typically use the C_4 photosynthetic pathway; the proportion of grasses which use the C_3 photosynthetic pathway typically increases with increasing latitude (i.e. under more temperate conditions).
    - Savannas typically occur under highly seasonal rainfall / moisture conditions, where grassy and leaf litter fuels dry out and become more flammable as the dry season progresses.
- Flammability
    - Savannas constitute the most fire-prone systems on Earth. Fires may be caused by lightning, but under contemporary patterns of human occupation and land use, most fire ignitions are started by people.

Savanna burning activities

- 'Savanna burning' or 'savanna fire management' for the purposes of this report is a technical term which describes fire management activities which assist with reducing greenhouse gas emissions from human-caused savanna fires.
- Savanna burning activities typically involve implementing prescribed fire management from early in the dry season to reduce the risk of typically more intense and extensive fires later in the dry season.
- Prescribed early dry season fire management can be applied strategically—for example, burning protective strips around important cultural or agricultural assets, protecting creek lines, and implementing precautionary burning at sites / along tracks which historically have proven to be a fire problem.

Savanna fire management methodologies

- Abatement
  - Abatement methodologies account for reducing emissions of accountable greenhouse gases (methane—CH_4; nitrous oxide—N_2O) against a pre-project baseline of a number of years in a defined project area.
  - The abatement produced through the implementation of savanna fire management activities is calculated for each project year as the change in greenhouse gas emissions with respect to the mean pre-project baseline.
  - In Australian savannas, the pre-project baseline is set as the calculated mean annual emissions over the preceding 10 years for savannas receiving a long-term average of >1000 mm rainfall per year, and the preceding 15 years for savannas receiving a long-term average of 600 – 1000 mm rainfall per year. These values are with respect to a couple of fire cycles (i.e. a couple of fire return intervals for the regions). As fires are potentially less frequent in certain regions (for example, South-East Asia (SEA)), note that these baseline periods are likely to need to be extended considerably in order to capture a number of fire return times in these circumstances.
- Sequestration
  - Sequestration methodologies account for the accumulation of carbon (C) under less severe fire regimes into long-term C pools, which may include in living plants (both above- and below-ground), dead fractions (e.g. litter, sticks, logs—also called coarse woody debris), and as part of soil organic matter.
  - In this context, note at this stage that Australia does not currently have an approved sequestration method – although a method is under development for sequestration in the dead fraction, or debris pools. There are currently no plans to include trees in a savanna sequestration method. There remain considerable challenges with respect to sequestration method.
  - Sequestration produced through the implementation of savanna fire management is calculated and averaged over extensive time periods (e.g. 25 – 100 years), depending on national and/or international criteria. This requires the implementation of the fire management activity for the duration of the period sequestration is being accounted for.

    - The increase in any one of the above C pools could be measured directly (which is technically very challenging at landscape scales and with known large inter-annual fluctuations in response to fire), or much more efficiently modelled with respect to predicted changes associated with fire regime characteristics. For example, knowing the rate at which trees grow under varying fire regime, it should be possible to predict the long-term amount of sequestration which could be delivered in a given period.

- Feasibility
    - In comparison with sequestration methodologies, procedures for calculating emissions abatement are relatively straightforward when the right information is available.
    - Whereas abatement and resulting carbon credits are calculated annually with respect to pre-project baselines, whereas sequestration projects require longer periods of time to demonstrate that they are achieving desired outcomes.
    - Sequestration projects thus need to be able to demonstrate that they can be implemented under conditions where tenure and operational arrangements are highly secure.
    - Despite these limitations, and keeping in mind the considerable methodology development challenges ahead, sequestration projects would deliver more carbon credit benefits if credited in conjunction with abatement projects on the same project land.

(2) Cultural feasibility

Assessing the cultural receptiveness or appropriateness of formal savanna fire management activities is the first project pre-condition.

- Does the community recognize that there is a fire management problem?
    - If no savanna fire management problem exists there is no reason to proceed.
    - If a savanna fire management problem exists but there is little awareness of it by the community, then nothing further should be done except perhaps for further information sharing with the community.
    - If the community perceives that there is a problem, is implementation of savanna fire management activities likely to be culturally acceptable? For

example, while a community may indeed recognize that they have a fire problem, their cultural solution may be to either ban fires (which is unlikely to be effective) or undertake extensive fuel mitigation/fire management activities after the first rains at the start of the rainy season. It should be noted that accountable savanna fire management practices rely on the undertaking of early dry season fire management to restrict the extent and frequency of fires late in the dry season.

- Does the community perceive that savanna fire management activities may have broader economic/cultural benefits?
    - Where early dry season fire management is considered by the community to be a feasible and potentially useful activity, it is essential to stimulate a broader consultation within the community to allow them to assess for themselves how a savanna fire management project might help meet other economic and cultural aspirations. For example, does it integrate well with existing cattle management requirements?

(3) Technical requirements:

3.1 Geographic Information System (GIS)

Assuming there is an identified late dry season wildfire problem, and that respective communities can see benefit in pursuing a savanna fire management project, there are various technical requirements which need to be met to first estimate the potential economic benefits and, subsequently, implement the project itself. The first is a functional GIS, including trained and available operators

- Mapping products for defining the potential project area.
    - Adequate scale mapping (at least 1:100,000) available digitally, describing at least district/regional administration boundaries, tenure, broad vegetation classes based on robust research, land use.
    - Reliable/indicative fire mapping products at a monthly/seasonal time step (derived from satellite imagery at 1:250,000 [e.g. MODIS] at least) for describing and assessing contemporary fire patterns, and recent fire history from at least 2000 (coincident with start of MODIS fire mapping archive).
    - Both vegetation and fire scar mapping needs to be validated, and should be available to be printed out/overlaid for community consultation purposes, ultimately to identify those areas of prospective 'natural/semi-natural' flammable vegetation which require better management.

- GIS (Geographic Information System) capacity.
    - Although intrinsically related to the initial mapping assessment described above, there is clearly an associated requirement to assess existing institutional capacity, and future requirements for training and implementation of on-going GIS needs.
    - Hence, who can provide initial GIS support and what steps need to be taken to ensure on-going service provision needs to be identified.

3.2 Parameters required for informing an abatement methodology

In its most basic form, savanna burning emissions for any defined project region (E) are calculated as the product of the mass of fuel pyrolised (FP) and the emission factor (EF) of respective accountable GHG (g) species:

$E = FP * EF(g)$

Where:

FP is the product of the area exposed to fire (A) taking into account spatial patchiness (P), the fuel load (FL) in respective fuel classes (FC) and respective fuel types (FT), and the burning efficiency (BEF) defined as the mass of fuel exposed to fire that is pyrolised.

EF(g) is defined relative to the fuel elemental content where, for carbon species, EF(g) is expressed relative to fuel carbon, and nitrogen species are expressed relative to fuel nitrogen. Fuel carbon mass is determined from fuel mass by the fuel carbon content, while fuel nitrogen is derived from the fuel mass by the product of carbon content and the fuel nitrogen to carbon ratio.

Research needs to define all these parameters for each vegetation class, in addition to defining the end of the EDS and the start of the LDS regionally for new areas.

As undertaken in Australia, savanna burning emissions (E) are calculated separately for early (EDS) and late dry season (LDS) periods for each vegetation fuel class. By convention, in Australian projects, the EDS is defined as fires occurring before the end of July (i.e. under relatively mild fire-weather conditions), and LDS fires are defined as occurring after that time.

- To calculate *FP*
    - Mapping of burnt area, typically from MODIS or finer resolution (e.g. Landsat) imagery, where mapping is undertaken both in early and late dry season periods, for the previous 5+ years.

- (*P*) Fire patchiness, is derived from field studies undertaken separately in both early and late dry seasons, where the proportion of the area typically burnt by fires in respective seasons is estimated
- (*FL*) Fuel load comprises the quantity of available fuels in the following classes (*FC*): *fine fuels* (grass and leaf litter), *coarse woody fuels* (sticks and small logs <5 cm diameter), *heavy woody fuels* (logs >5 cm diameter), shrubs (i.e. with stems <5 cm Diameter at Breast Height—DBH). Fuel loads in respective fuel classes are derived from extensive field studies that describe relationships between fuel accumulations with time-since-last-fire (i.e. 1, 2, 3, 4, 5…years since fire). Separate sets of fuel load accumulation relationships are derived for each vegetation fuel type (*FT*)—e.g. major vegetation structural types (such as open forest, woodland) occurring on productive sites with fertile clay soils, or alternatively on less productive sites with sandy soils.
- (*BEF*) The Burning Efficiency Factor describes the proportion of the available fuel in respective Fuel Classes and Fuel Types that is consumed by fire in each fire season. BEF is derived from extensive fire treatment studies that typically involve sampling of available fuels before burning, and a subsequent post-fire assessment. Fire intensity is proportional to fire severity. In Australia, low severity fires are those which are either substantially patchy and/or result in leaf scorch mostly <2 m height; moderate severity fires are those where leaf scorch is >2 m but does not affect the canopy; high severity fires are those where the canopy is affected. To derive a single BEF value for respective seasons, it is necessary to take into account the proportional occurrence of fires of respective severities. In north Australian studies the respective proportions of fires of different severity have been derived from extensive observations made from long-term ecological monitoring plots. In terms of Australian SFiM methodologies, note that only two severity classes are used – 'low' severity for the EDS, and 'high' for the LDS.
- *Calculation of FP in the GIS*: As described above *FP* is the product of above parameters that can be calculated using the GIS for an appropriate pixel size, typically 1 ha (i.e.. 100 X 100 m). Knowing when any one pixel was last burnt (year, season) and the fuel type (*FT*), one can apply appropriate fuel accumulation values for respective fuel classes (*FC*), fire

patchiness (*P*) and ***BEF*** parameters for respective seasons, and hence calculate ***FP***.

- To calculate ***EF(g)***
  - Characterisation of emission factors for the accountable greenhouse gases methane (CH_4) and nitrous oxide (N_2O) typically requires substantial field assessment involving the direct measurement of the proportion of CH_4 and N_2O gaseous products (i.e. in smoke) from fires burning respective fuel class components under different fuel type conditions. Substantial work undertaken in Australia has shown that, under fully cured fuel conditions, there is no seasonal differentiation in the proportional emissions of CH_4 and N_2O in smoke.
  - As noted above, for calculation of EFs the proportions of carbon (C) and nitrogen (N) in respective fuel class components also needs to be known. These values may be obtained by undertaking assessment of the chemical composition of dry fuel class components, or alternatively derived from available scientific literature.
  - Where such detailed studies above have not been undertaken, EF values for CH_4 and N_2O and carbon and nitrogen ratios may be applied from available pertinent scientific literature if there is evidence that they are comparable.
  - GHG emissions of CH_4 and N_2O are reported in units of carbon dioxide equivalent (CO_2-e), which takes into account the proportional molecular mass of C and N in respective CH_4 and N_2O molecules, multiplied by the 'greenhouse gas warming potential' of respective gases relative to CO_2, with the greenhouse gas warming potential values published in Australia through the National Greenhouse and Energy Reporting Scheme.
- Calculating emissions abatement
  - Application of the emissions calculation equations given above are used for each calendar year to estimate savanna burning GHG emissions for respective 1 ha pixels summed for the entire defined project area.
  - Calculation of any abatement achieved through the imposition of strategic EDS fire management is undertaken, as noted earlier, with reference to the mean pre-project emissions baseline. In addition to determining if there is available satellite imagery to detect fire scars during the EDS and the LDS

in the project area, it is essential that there are detailed images for the entire baseline period so that the baseline average annual emissions can be determined for a project area.

- In Australian savanna fire management projects, the pre-project baseline is set as the mean annual emissions over the preceding 10 years for savannas receiving a long-term average of >1000 mm rainfall per year, and the preceding 15 years for savannas receiving a long-term average of 600 – 1000 mm rainfall per year.
- In respect of frequency, note that the justification of the length of the baseline period in Australia (10 yrs. in high rainfall and 15 years in low rainfall) is that these time periods cover a period when two to three fires would naturally have occurred in every pixel, to account for inter-annual variation in fire occurrence. Where fire frequency in other savannas is significantly less than in Australian savanna, an approach to determine a realistic, conservative appropriate baseline could be considered. In addition, as the period of time between fires increases, as in some regions outside Australia, there is an increasing probability that EDS fire management will become less effective in mitigating LDS fires. In these conditions there may be a lower probability of fire returning to the area in 1-2 years post EDS fire management, and a greater probability that fire will return when fuels are approaching their equilibrium/maximum levels. When this occurs there may be greater potential for LDS fires to propagate across the land, with little to no influence from EDS burning that occurred several years earlier.
- Note also that the Australian method stipulates that emissions from any fossil fuel use must be deducted from the abatement (e.g. vehicles, aircraft, etc.). The method also has an 'uncertainty buffer' to account for years of net negative abatement where project emissions are greater than baseline emissions. This uncertainly buffer would need to be re-calibrated in new regions based on fire activity in that region.
- Each tonne of carbon dioxide equivalent (t.CO_2-e) abated, has the value of 1 carbon credit.

3.3 Parameters required for informing a sequestration methodology and significant issues affecting 'permanency'

- Sequestration methodologies involving the enhanced storage of carbon in association with savanna fire management approaches are potentially feasible for soil organic matter (SOM), dead organic fractions (e.g. litter, coarse woody debris (CWD)), and living woody biomass (especially trees). Note, in this context, a considerable amount of research is still required to confirm whether sequestration - particularly in soils and trees - is achievable with alternate fire practices, and then to quantify these changes.

- Although developed methodologies for all above components may have potential, attempts to develop robust methodologies in Australian savanna systems have, to date, proven to be complex. For example, while modelling studies predict that sequestration of SOM is potentially feasible over decadal scales, a large number of field-based studies have provided little support. This is primarily due to differences in time scale, and the point based nature of sampling in a system that shows large inter-annual fluctuations. A modelling approach adjusts for inter-annual fluctuations to provide an average annual change. Note that SOM is rapidly oxidized in savanna wetting and drying cycles, and measurements are notoriously variable, even at small spatial scales.
- Recently, a model-based approach for sequestration in CWD fractions has been developed and is currently under technical assessment. The modelling relies on fuel load accumulation and decomposition rates of decay for existing vegetation fuel types dependent on the frequency of fire in the EDS and LDS. A version of this methodology for higher rainfall savannas is likely to be approved for implementation in coming years.
- There is a potential that implementing more benign fire regimes may increase sequestration in living biomass. Significant challenges, however, remain to determine whether there are long term and permanent changes in living biomass as result of a change of fire management. Note that changes in savanna biomass (tree) pools are currently not required in the inventory, and including them requires significant work should it be possible at all.
- As well as the above technical issues, by definition, sequestration projects must manage accrued carbon stocks over the longer term—at least for decadal time-frames, for example from a minimum of 25 years (currently) to 100 years (previously) in Australia, depending on which national or international framework is applied. As such, sequestration projects must demonstrate that their outcomes provide 'permanency'. Implementing continuous and effective savanna fire management over such timeframes clearly has its risks (including for investors), and requires legal and regulatory certainty (including for supportive tenure

arrangements). As such, sequestration projects are likely to face many development and implementation difficulties in all country settings.

(4) Legal, equity, governance and capacity issues

- Legal and policy issues
    - Where fire policy and legislation are based on fire suppression or prevention, reform may be needed to facilitate fire management activities.
    - Legislative reforms may be needed to facilitate communal, community based land management.
    - In many savanna settings, land tenure arrangements are complex. Note, however, that an advantage of fire management is that, for emission abatement activities at least, it can and has been implemented on a fee for service basis. This means that land access rather than land tenure may be sufficient to enable fire management operations in some circumstances.
    - Issues around rights over carbon may be uncertain and may require clarification in some jurisdictions.
    - The capacity to engage in carbon markets through SFiM may require aligning abatement to any national/international accounting schemes so that generated carbon abatement can be credited.
    - Whether emissions from savanna burning are included in the relevant National Greenhouse Gas Inventory is an important contextual factor for SFiM readiness.
- Equity and rights concerns
    - For the interests and rights of Indigenous peoples and local communities to be respected, emissions abatement fire management programmes must not override community land use objectives. Programmes should also consider other biodiversity and ecological implications of the proposed management approach, including cultural and economic use of natural products. Local ownership must not be lost.
    - Effectively operationalizing prior informed consent, an essential element of respect for the right to self-determination of Indigenous peoples, is a difficult practical issue. Greater experience of what this requires in the savanna fire management context is needed.
    - Acceptance of market-based approaches among indigenous and local communities is not universal. Some communities are likely to prefer alternative approaches to realizing the sustainable livelihood benefits of savanna fire management.

    - Cultural change towards greater respect for indigenous knowledge systems in some regions may be needed to support integration of traditional fire knowledge within public policy.

- Governance issues
    - In some areas, there is a lack of clearly defined processes, roles and responsibilities for decision-making on communal land. Local-level governance systems may be inexperienced in managing multiple and conflicting land use objectives.
    - Communities need a local social organization or structure to implement annual burning – or any other management activity – in a planned and structured manner. Effective governance at the community level is also needed to ensure that social co-benefits are realized, such that payments are distributed equitably among the community, or otherwise used in ways that support the needs and aspirations that the communities themselves define.
    - Consideration of how to reconcile traditional governance models with those expected by donors and markets is required.
    - Depending on the role of government in the design and implementation of fire management activities, governance issues may also arise at that level.
    - Governance issues akin to those that have been articulated in the context of REDD+ may be relevant.

- Capacity needs (see also sections above)
    - Operationalizing fire management at landscape scales in developing countries will require significant levels of capacity development across many disciplinary areas, and among many different actors. These include from within communities, local organisations, research institutions and governments. For example, Australian proponents estimate that it takes a couple of fire seasons to fully train up rangers to undertake the fire management.
    - Capacity needs extend across the scientific, social science, legal, governance and business administration fields. Note in this context that all Australian proponents use the Savanna Burning Abatement Tool (SavBAT) for estimating the quantity of abatement generated from the project fire management, as the manual calculations are very complex. To improve usability, a similar tool would need to be developed for other countries.
    - In-country technical capacity to implement accounting procedures for emissions abatement approaches would need to be developed.

- Further work on how to measure, generate and verify co-benefits is required in both developed and developing country contexts.

PART VI –SUMMARY OF FINDINGS OF THE REGIONAL FEASIBILITY ASSESSMENTS

The key findings for each of the regional assessments are summarised below. General conclusions for the applicability of methodology-based savanna fire management as used in Australia, are then described for each region.

Africa

KEY FINDINGS AFRICA

- The development and application of SFiM methodologies similar to those utilised in the Australian context is likely to be possible in parts of Africa, whose landscapes, of the three regions explored, most resemble Australian conditions. Given that African savannas contribute 71% of global savanna emissions, acute human needs, reliance by local peoples on fire management to support existing livelihoods, and limited alternative economic opportunities, methodology-based SFiM represents an important, promising and unique opportunity for the African savanna region.
- Based on climate, ecosystem, biodiversity and human interaction characteristics methodology-based SFiM is theoretically possible in settings any of the three African Savanna Sub-Regions. The Southern African Savanna Sub-Region is considered more comparable to the northern Australian context and was identified as the most feasible for methodology-based SFiM application.
- Within the Southern African Savanna Sub-Region, which covers approximately 5 million km^2 and is comprised of 16 countries, two areas have been identified as the most promising:
    - The Kavango-Zambezi (KAZA) Sub-Region situated in the Okavango and Zambezi river basins where the borders of Angola, Botswana, Namibia, Zambia and Zimbabwe converge. The KAZA Transfrontier Conservation Area (KAZA-TFCA), the world's largest, incorporates a host of protected areas (PAs) and affords a unique position to foster integrated natural resource solutions across a largely intact landscape.
    - The Luangwa Valley Sub-Region in Zambia is one of the largest unaltered river systems in southern Africa, supports Africa's largest population of hippopotamus and is representative of the vast Southern Miombo Woodlands. The upper and middle parts of the river valley contain North Luangwa and South Luangwa national parks.
    - Based on all criteria, pre-feasibility site assessments (available separately), were developed for:
        - The region around the Bwabwata National Park of North East Namibia; and,
        - A cross border approach in the KAZA Sub-Region.

a) Vegetation and fire ecology setting

- Africa is the world's second largest continent covering 30 million km^2, half of which can be described as savanna. Classified within the *Tropical and Subtropical Grasslands, Savannas, and Shrublands Biome,* they form a contiguous band around the central African rainforests creating a transition zone between moist forests and arid deserts.

- The scale and diversity of African savannas presents challenges in terms of being able to broadly define their characteristics, however, comparable environmental conditions to those found in northern Australia certainly exist. Similarities can be observed in topographical make-up (largely occurring on flat landscapes of infertile soils), seasonality (possessing distinct wet/dry seasons) and in temperature (retaining high heat indexes year-round).

- The heterogeneous nature of savanna is driven by complex variation in climate, soil, topography, fire, browsers, grazers, and human interactions that dictate structure and function. Importantly, Australian and African savannas are characterized as fire-dependent ecosystems, with their ecological processes, structure and species composition evolving with, and inextricably linked to, fire activity. To enable broad regional assessment and comparison with northern Australian savannas, three savanna sub-regions (East, Southern and West African) have been defined based on geographical, climatic and compositional similarities.

- Africa is the second most populous continent in the world (920 million in Sub-Saharan Africa) and rural population densities are generally much higher than the northern Australia savanna setting (as low as <1 person km^2). The East and West African Sub-Regions are relatively fertile and support very high population densities often upwards of 50 persons/km^2. In contrast, the Southern African Sub-Region is largely infertile and population densities rarely exceed 20 persons/km^2 (with large areas supporting considerably less).

- African savannas occur under more markedly seasonal rainfall conditions than Australian savannas, which exist in areas of lower and less seasonal rainfall due to higher soil fertility. The African Tropical Zone with Dry Seasons is the most comparable to northern Australia's and dominates the Southern African sub-region and a considerable proportion of the West African sub-region. Dry seasons last more than six months and tend to increase in length with distance from the equator, and annual precipitation ranges between 600 to 1,200 mm with pronounced inter-annual variation.

- African savannas are commonly divided into wetter nutrient-poor savannas growing on infertile soils, and drier nutrient-rich savanna growing on fertile soils. High mammalian and insect herbivore populations in fertile savannas consume fuel loads and subsequently reduce fire frequency. In the West African sub-region, the role of domestic animals and low rainfall explain savanna vegetation patterns. In East Africa wild ungulate's migratory patterns are considered crucial elements; and in Southern African savanna research has emphasized fire as a main savanna structural driver.

- The biodiversity of African savannas include many charismatic and endemic large mammal groups including, elephants, rhinoceros, hippopotamus, lions, leopards and the african wild dog, as well as an assortment of wild ungulates. Most savanna ecoregions possess more than 1,000 plant species, with the Central Zambezian Miombo Woodlands of the Southern Savanna Sub-Region exhibiting the highest with 3,800 recorded plant species. Africa has over 2 million km^2 of protected areas with the savanna ecoregions tending to be best represented, particularly those of East and Southern Savanna sub-regions.

b) Observations on the potential for development of savanna fire management methodologies and technical requirements:

- The higher rural population densities and different land use practices within African savannas are important in affecting regional patterns of burning. Savanna fire management depends on the availability and arrangement of fuel, and is largely determined by climatic factors. However, human interaction and associated reduction (cattle density) and fragmentation (roads / cultivation) of fuel loads is important at the landscape scale. Increasing human population densities up to approximately 10 persons/km^2 are associated with more fires, but densities higher than 10 persons/km^2 are associated with fewer fires. SFiM is most feasible in areas with population densities less than 5-10 persons / km^2.

- Uncoordinated savanna burning results in LDS fires, characterized by high intensity, low levels of patchiness and a tendency to spread due to hot, dry and windy conditions throughout much of Africa. Frequent (annual-biennial) large-scale uncontrolled LDS wildfires, comparable to the northern Australian context, exist in sparsely populated rural settings, particularly in and around protected areas. These settings are the most feasible for methodology-based SFiM application.

- An avoided deforestation VCS methodology already exists for the Miombo woodlands of Tanzania, and may be adaptable to some other parts of the sub-region. In-depth work would be required to develop emissions abatement methodologies akin to those used in Australia.

c) Cultural, legal, equity, governance and capacity context

- Anthropogenic fires have been critical in shaping African savannas over the last 1.5 million years with humans possessing significant control over fire regimes and biomass burning for at least 400,000 years. As such, savanna people and their contemporary land use are fundamental to SFiM application, particularly as African savanna supports large populations.

- The five distinct ethnic groups originating within African savannas all evolved in comparable environments and developed markedly similar traditional fire knowledge to manipulate savanna landscapes. Application of small fires throughout the dry season typically created a seasonal mosaic landscape, annually re-created by people, and consisting of unburned, early-burned, and recently burned patches.

- Traditional fire knowledge (TFK) remains largely intact in the more remote African settings and continues today in the form of traditional burning to support contemporary rural livelihoods of many African people. Traditional burning is most important, and is frequently used to support subsistence livelihoods of remote communities. It includes slash-and-burn agriculture, livestock grazing improvements, charcoal production, natural product harvesting, controlling pests, hunting and reducing wildfire threats.

- Insufficient and inconsistent land and fire management policies and legislation, administered by centralized governments with limited capacity, inadequately address the appropriate use of fire.

d) Current promising sub-regions

- Dwarfing the scale of Australia's comparable biome, Africa is the world's second largest continent, covering 30 million km^2, half of which can be described as savanna. Ecosystem characteristics comparable to northern Australia are likely to exist throughout the scale and diversity of African savannas, however, the large populations (920 million in Sub-Saharan Africa: PRB, 2014) they support determines if the application of SFiM is theoretically possible in quite distinct settings.

- Based on climate, ecosystem, biodiversity and human interaction characteristics methodology-based SFiM is theoretically possible in any of the three African Savanna sub-regions. The Southern African Savanna sub-region is considered more comparable to the northern Australian context and was identified as the most feasible for methodology-based SFiM application.

- Within the Southern African Savanna sub-region, which covers approximately 5 million km^2 across 16 countries, two areas were identified as the most promising:
  - The Kavango-Zambezi (KAZA) sub-region is situated in the Okavango and Zambezi river basins where the borders of Angola, Botswana, Namibia, Zambia and Zimbabwe converge. The KAZA Transfrontier Conservation Area (KAZA-TFCA), the world's largest, incorporates a host of protected areas (PAs) and affords a unique position to foster integrated natural resource solutions across a largely intact landscape.
  - The Luangwa Valley sub-region in Zambia is one of the largest unaltered river systems in southern Africa, supports Africa's largest population of hippopotamus and is representative of the vast Southern Miombo Woodlands. The upper and middle parts of the river valley contain North Luangwa and South Luangwa National Parks.

e) Based on all criteria, pre-feasibility site assessments (available separately) were developed for:

- The region around the Bwabwata National Park of North East Namibia; and,
- A cross border approach in the KAZA Sub-Region.

KEY FINDINGS LATIN AMERICA

- In Latin America the savanna environments are varied and diverse, as are the social and governance contexts in which the savanna regions are found. Several savannas are flooded periodically, have patch mosaic characteristics, and incorporate important pockets of other forest types including rainforest. The extent to which the Latin American savannas resemble Australian conditions varies across the region.
- Despite long histories of fire management by the region's Indigenous peoples, fire policy has largely focused on prohibition and suppression. With the significant economic, environmental and human cost of the intense wildfires that have taken hold in the region regularly over past years, some programmes have already been introduced in the region to encourage and introduce strategic fire management as an alternative policy approach. These programmes have already built some technological readiness and human capacity for SFiM in the region, alongside strengthening the interest of governments and communities in Indigenous-led SFiM.
- While the application of SFiM methodologies similar to those utilised in the Australia context are likely to be possible in parts of the region, a significant amount of further work on the ground will be required to facilitate their introduction.
- Based on all criteria, pre-feasibility site assessments (available separately), were developed for:
  - The Cerrado of Tocantins State, Brazil;
  - The Gran Sabana of Venezuela in the area around the Canaima National Park; and,
  - The Pine Savannas of Belize.

Latin America

a) Vegetation and fire ecology setting

- For the purpose of this assessment, Latin America is defined as covering all Central and South American countries, including the Caribbean. 260 million hectares of savanna exist across several countries in the region including in: Belize, Bolivia, Brazil, Colombia, Cuba, Guyana, Honduras, Mexico, Nicaragua, Paraguay, and Venezuela.

- Significant savanna sub-regions include the Cerrado of Brazil and Paraguay (76% of the total savanna areas) the Gran Sabana of Brazil, Venezuela and Guyana, and the Llanos of Venezuela and Colombia (28 million hectares).
- Each of these sub-regions has distinct characteristics:
    - Llanos is characterised by a high level of heterogeneity in landscape and vegetation, highly flammable C3 and C4 grasses, seasonal flooding and areas of fire sensitive gallery forest and deciduous dry forest. The Llanos is rich in biodiversity, however, unlike the African savanna, few ungulates are present. The Llanos is affected by high rates of deforestation and land conversion. Limited areas of national park are present. Several indigenous groups occupy the region, with fire being an integral part of traditional land management practice.
    - Cerrado vegetation varies from an open field to a tall closed forest. The climate is tropical and seasonal. The dry period, from May through September or October, coincides with the coldest months of the year (Nimer, 1979). The average annual rainfall varies between 1,250 and 2,000 mm, and the average annual temperature ranges between 20° and 26° C. Cerrado harbours a very distinctive biota, with thousands of endemic species. Approximately 67% of the cerrado ecoregion has been significantly altered by human activities. Each year, the Cerrado is affected by uncontrolled wildfire, with impacts on biodiversity, livelihoods and emission contributions. While there are programmes developing integrated fire management in the region, government policies continue to be based on fire prevention and suppression. Several indigenous groups of the Cerrado have traditionally used sophisticated fire management practices towards a range of livelihoods objectives.
    - The Gran Sabana occurs in three large patches across northern Brazil, extending into Guyana, Suriname, and Venezuela. "Islands" of small savanna patches also occur along the north-west portion. Fire-sensitive moist forests are embedded within the landscape isolated from each other and other similar habitats, and containing a number of endemic species. The Gran Sabana occupies an area within the Roraima geological formation and is distinguished by extensive savanna and scrub vegetation. The region is traversed by streams, extensive savanna and, similar to Llanos and Cerrado, gallery forests. The plant cover of the Gran Sabana is an intricate mosaic, constituted by numerous types of vegetation. In the northern region the

Gran Sabana contains vast expanses of C4 grasses and fire dependent vegetation with fire sensitive broadleaf and riverine forest systems embedded in the flammable landscape. Average temperatures are around 20°C and average rainfalls are between 2,000 and 3,000 mm. There is a weak dry season from December to March. In Guyana, at least one dry season occurs each year, and two during most years Humidity across the region is high with mean annual readings between 75–85%. Degradation of remaining forests into grasslands, due to either natural or human induced fires, is the most important threat to vegetation. Habitat fragmentation caused by fires results in the gradual extinction of species that cannot adapt to the degraded habitats. While current policies focus on prevention and prohibition of fire, the indigenous population has traditionally practiced fire management. The reduction in indigenous burning on a large-scale has likely resulted in increased fuel loads, causing large-scale, historically rare, severe fire events.

  - Other smaller regions of savanna exist in Central America and the Caribbean, including the pine forests of Belize, Mexico and Guatemala. In Belize, due to increasing immigration from adjacent countries and expanding agriculture, fire frequency is increasing in the dry season and fire size is expanding. Crop losses due to wildfire from dry-season ignitions from hunters and farmers threaten reproduction of pine species killing seedlings and impacting the future of existing sustainable logging operations and future habitat of the endangered yellow-headed parrot. Severe fires during the dry season also induce mortality in adjacent broadleaf ecosystems. Dry season savanna fires reach into the fire-sensitive vegetation on the slopes of the Maya Mountains, causing soil erosion to Kechi and Mopan Maya villages and degrading soils used for milpa farming and impacting water quality.

- In general, South American savanna faces significant threats. With the on-going expansion of agriculture, they are under going rapid conversion, with 71% of the South American savanna having been converted to croplands and 5% now urban areas (White *et al.,* 2001). Intense, destructive wildfires in savanna are a significant problem in the region, resulting in great economic costs and causing damage to infrastructure and biodiversity.

- There is growing recognition in all savanna sub-regions of Latin America that severe dry season wildfires have negative impacts upon public health and safety due to the direct impacts of particulate emissions and regional haze during peak burning seasons.

- Fire-induced crop loss and impacts upon local and regional livelihoods are increasingly untenable as the population increases and fires become more frequent. Tourism and visitor enjoyment has been impacted by smoke events, thus affecting important income streams.

- In all savanna sub-regions analysed, fires are impacting biodiversity due to severe impacts on fire-sensitive forests adjacent to or embedded in fire-prone savanna. Beyond biodiversity concerns, destruction of forested areas decreases the carbon sequestration capacity of standing forests.

b) Observations on the potential for development of savanna fire management methodologies and technical requirements:

- The savannas of the region demonstrate both similarities and differences to Australian conditions, and to other savannas within the region. Each sub-region thus requires separate analysis and consideration when assessing the potential for SFiM that draws from the Australian experience.

- In all of the above savannas and perhaps others in the region, (i.e. Mexican savannas and the Miskito savanna of Honduras and Nicaragua) the application of methodology-based Savanna Fire Management is likely to be theoretically possible upon the development of locally appropriate methodologies.

- Some emissions data is available for the Cerrado. In Belize, baseline data are available on the frequency, extent and intensity of wildfire in and around the savannas of southern Belize, although noting some limitation in historical data. Baseline data are available on carbon stocks in the savannas of southern Belize and adjacent ecosystems affected by savanna fires. At present, there is no methodology for verifying carbon stocks or emissions from Belizean pine savannas. This would require therefore require development and testing.

- While a great deal more work is required across the scientific, technical, demand side, and legal and policy domains, much of the capacity to operationalize the potential of SFiM including through development and application of methodology-based approaches, exists in the region.

c) Cultural, legal, equity, governance and capacity context

- Indigenous peoples in all sub-regions have long histories of fire management. They have used fire for a range of cultural, livelihoods and ecological management purposes. There is also increasing interest in the role of indigenous people and their traditional knowledge of fire use throughout the region. In some areas governments are beginning to recognize the benefits of partnerships with tribes, working together to solve problems associated with severe, large-scale wildfire events.

- Policy and legislation frequently focus on prohibition and suppression, despite scientific evidence demonstrating the benefits of a more integrated fire management approach. Some important programmes are in place to explore and demonstrate the benefits of a fire management approach, such as in the Cerrado of Brazil. In countries such as Belize, appropriate policies exist although with little implementation.

d) Promising sub-regions

- Based on all criteria, sub-regions that appear to demonstrate the most potential for SFiM at the time of writing include:
    - The Cerrado of Brazil;
    - The Gran Sabana of Venezuela; and,
    - The Pine Savannas of Belize.
- Based on the range of considerations identified in the pre-conditions checklist, site pre-feasibility assessments (available separately), were completed for:
    - The Cerrado of Tocantins State Brazil;
    - The Gran Sabana of Venezuela in the area around the Canaima National Park; and.
    - The Pine Savannas of Belize.

KEY FINDINGS ASIA

- In Asia, while savanna ecosystems share many characteristics with tropical north Australia, the population density, highly fragmented landscapes and high historical rates of conversion of savanna suggest that different models for the reintroduction of SFiM may be more appropriate, notwithstanding the very significant benefits that improved fire management could bring to the region.
- Regions where SFiM would benefit local populations include the savanna areas of Timor Leste, Eastern Indonesia, the Transfly region of Papua New Guinea, and the savanna regions of Cambodia and Myanmar.
- Based on all criteria, a pre-feasibility site assessment (available separately), was developed for:
    - A cross border thematic approach across Timor Leste and the Province of Nusa Tengarra Timur, Eastern Indonesia.

Asia

a) Vegetation and fire ecology setting

- Based on the MODIS derived MCD12Q1 mapping product, countries with proportionally large 'savanna' extents include: Timor-Leste (38.5%, mostly woody savanna); China (38.4%, mostly grasslands); Afghanistan (33.4%, grasslands); Cambodia (30.9% mostly woody savanna); Myanmar (26.9%, mostly woody savanna); Nepal (24.6%, grasslands). Savanna vegetation is also found in Bangladesh, Bhutan, India, Indonesia, Laos, Pakistan, Papua New Guinea, Philippines, South Korea, Taiwan and Thailand.
- Within South East Asia, savannas in Cambodia and Myanmar are the most fire-prone, with mean fire frequencies of 0.127 (return period ~8 yrs.) and 0.0684 (return period ~14 yrs.) respectively
- However, regional-scale fire mapping data are likely to substantially under-report actual fire extents and frequencies in typical savanna habitats in the assessment region. Higher resolution spatial imagery products are required in the Asian context.

b) Observations on the potential for development of savanna fire mangement methodologies and technical requirements

- In terms of abatement, fire detection issues have significant implications for estimates of biomass burning emissions in the Asia assessment region. More suitable spatial imagery products are required to be used to support further work on abatement potential and to support monitoring over time.
- In terms of feasibility, to support sustainable livelihoods and environmental management, it is justified to apply prescribed strategic fire management from the early-mid dry season period to restrict the spread of late dry season wildfire. Building on well-documented traditional South East Asian swidden practices, applying such methods will reduce fire emissions, enhance biomass and soil carbon conservation, and provide a range of tangible rural livelihood and ecosystem services benefits.
- Major differences between benefits derived in Australian and South East Asian savanna settings are 1) vast spatial opportunities for generating carbon benefits under Australian conditions, and (2) spatially restricted, but very substantial livelihood and environmental benefits in densely populated rural South East Asian settings. The latter carbon credit benefits, while relatively small in quanta, need to be considered more broadly within local community contexts—for example, as part of developing integrated land management and livelihoods approaches at catchment scales.

c) Cultural, legal, equity, governance and capacity context.

- Swidden cultivation - a land use system that employs a natural or improved fallow phase, longer than the cultivation phase of annual crops, and sufficiently long to be dominated by woody vegetation, and cleared by means of fire - has traditionally and continues to be widely used in South East Asia. Details of these practices vary according to cultural settings.
- Relatively little information is available for land use practices in more open, less woody (derived or natural) savanna environments in the Asian region. However, under such conditions pastoral activities and associated burning practices appear to assume greater prominence in the mix of livelihood options.
- Communities often recognise that there are fire management problems. While initial drivers away from swidden and other uses of fire in land management may appear to involve increasing population pressure and development of more settled forms of agriculture, equally significant are: (1) the breakdown in traditional management systems, including cultural regulation over the use of resources and management of fire and (2) tenure disenfranchisement and broader political

agendas imposed on traditional farming practitioners by states and their agencies, especially in relation to commercial forestry and agricultural interests.

- Zero burning and other restrictive policies and legislation are present in the region in part as a response to transboundary haze issues.
- Policies largely fail to recognise the practical livelihood and environmental benefits that effective swidden and other fire management systems can deliver. Consequently, there is room to raise awareness among policy makers of the value of SFiM and its potential benefits for the region.
- Erosion of customary rights and limitations and complexity in land tenure and land management rights may have implications for local communities to engage in the undertaking of GHG emissions mitigation and offset projects.

d) Current Promising Sub-regions

- At present, there is insufficient reliable information to draw any useful conclusion about the location, or prioritization, of potential savanna fire management projects generally, in much of continental South East Asia. For example, while countries (such as Cambodia) with large tracts of savanna would appear at first instance to be among the most promising candidates, such relevant information as exists for Cambodia addresses mostly forest swidden systems and only one geographically restricted published study describes cultural burning practices in savanna.
- Nevertheless, considerable contextual ethnographic and some technical data is available, both for fire-prone savanna landscapes of the semi-arid eastern Indonesian Archipelago (especially NTT), and contiguous Timor-Leste. Given and assuming government and community interest and demand, suitable sub-regions for improved SFiM in the short to medium term include:
  - o Timor Leste; and,
  - o Nusa Tenggara Timur, Indonesia.
- In time, SFiM activities in promising sub-regions have the potential to raise the awareness of the value of SFiM across the broader region.

e) Initial suggested site areas for the development of a pre-feasibility site assessment or other proposal type:

- A proposal focusing on a cross border, thematic approach across Timor Leste and Eastern Indonesia has been developed and is available separately. The proposal, pending the further development of an evidence base and assuming further community and government consultation and support, could also be adapted to include a catchment based approach in Timor Leste/Eastern Indonesia, such as in the Beninain catchment region, or in an island setting such as Sumba or Flores.

- A focus on these sub-regions does not preclude SFiM in other sub-regions as also being feasible, should improved mapping tools, data sets and other sources of information later indicate this possibility.

Conclusions of Regional Feasibilty Assessments

- While the reintroduction of SFiM would have significant potential benefits in each of the three regions, local contextual factors mean that the feasibility and/or readiness for employing methodology-based approaches similar to those used in the Australian context, varies:

  Specifically, the assessments find that:

  - The development and application of SFiM methodologies similar to those utilised in the Australian context, is likely to be possible in parts of Africa, whose landscapes most resemble Australian conditions. Given that African savannas contribute 71% of global savanna emissions, combined with the acute human needs of the region, reliance by local peoples on fire management to support existing livelihoods, and limited other economic opportunities, methodology-based SFiM represents an important, promising and unique opportunity for the African savanna region.
  - In Latin America, the savanna environments are varied and diverse, as are the social and governance contexts in which the savanna regions are found. Despite long histories of fire management by the region's Indigenous peoples, fire policy has largely focused on prohibition and suppression. With the significant economic, environmental and human cost of the intense wildfires that have taken hold in the region regularly over past years, some programmes have already been introduced in the region to encourage and introduce strategic fire management as an alternative policy approach. These programmes have already built some technological readiness and human capacity for indigenous-led SFiM in the region, alongside strengthening the interest of governments and communities in indigenous-led SFiM. As in the case of Africa, while the application of SFiM methodologies, similar to those utilised in the Australian context, is likely to be possible in parts of the region, further work on the ground will be required to facilitate its introduction.

- In Asia, while savanna ecosystems share many characteristics with tropical north Australia, the population density, highly fragmented landscapes and high historical rates of conversion of savanna suggest that different models for the reintroduction of SFiM may be more appropriate, notwithstanding the very significant benefits that improved fire management could bring to the region.

- In each region, fire has been used over long periods of time by indigenous and local communities for a range of social, cultural and environmental objectives.
- In each region, traditional fire practices have been interrupted.
- In each region LDS burning is contributing to GHG emissions, damaging ecosystems and compromising the sustainable livelihoods and well-being of local indigenous and local communities.
- The reintroduction of SFiM would bring significant environmental, social and economic benefits in each region. Among those to benefit would be some of the most disadvantaged Indigenous and local communities in those regions, some of whose sustainable livelihoods have been undermined by interruptions to traditional fire management practices.
- The regions vary in the extent to which there is current scientific, technological, and regulatory readiness for the reintroduction of SFiM. Consequently, the type of support needed, and the pathways for reintroduction of practical SFiM in each region will be highly context dependent.
- The site pre-feasibility proposals provided, give some indication as what a context dependent approach may look like in each of the regions, offering a starting point for the further practical exploration of SFiM globally.
- While there are many practical challenges ahead, the steps required to build readiness for methodology-based SFiM are expected to be concrete and achievable over appropriate time scales and with well-targeted human, scientific, regulatory and economic investment.

PART VII – AFRICA

Africa is the world's second largest continent covering 30 million km^2, half of which can be described as savanna, dwarfing the scale of Australia's comparable biome (Sayre, 1999). Ecosystem characteristics comparable to northern Australia are likely to exist throughout the scale and diversity of African savannas. However, the large populations (920 million in Sub-Saharan Africa: PRB, 2014) they support determines that application of SFiM is theoretically possible only in quite distinct, albeit extensive, settings.

Anthropogenic fires have been critical in shaping the vegetation diversity, abundance, and distribution of southern African savannas over the last 1.5 million years (Hall, 1984, Brain and Sillen, 1988, Bond *et al.,* 2005). As such, savanna people and their contemporary land use are fundamental to SFiM application, particularly as the African savannas support such immense populations.

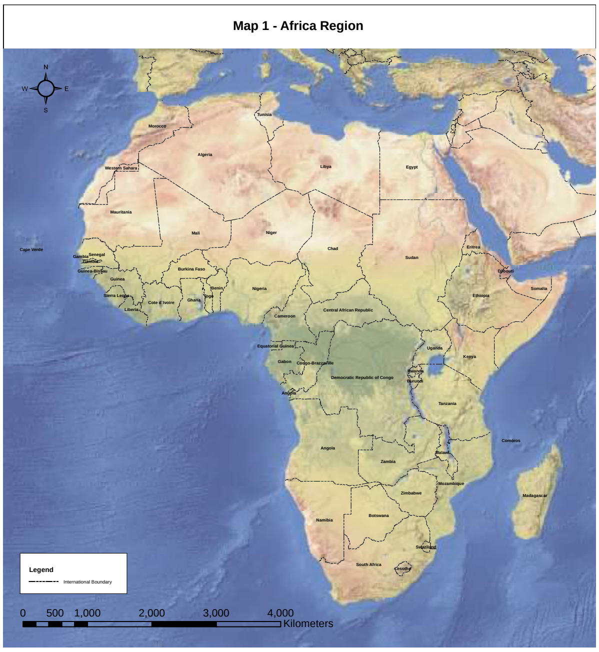
To determine if the fundamental environmental conditions (considered important for SFiM implementation) exist in the African region, the following overview is structured around a set of broad pre-conditions consistent with those identified in Part V of this report, and including:

1. A tropical climate with the expression of distinct wet and dry seasons;
2. The presence of fire-prone savannas; and,
3. The dominance of frequent (annual–biennial) large-scale LDS wildfires.

The overview provides a broad analysis of the African region, followed by detailed exploration of promising sub-regions, describing existing fire management scenarios, identifying the potential benefits and constraints to SFiM implementation and recommending promising sites for pilot implementation. Priority site pre-feasibility assessments are available separately and are structured in the form of project funding proposals to donors to encourage the funding of full project feasibility assessments.

African Landscape, Climate and Biomes

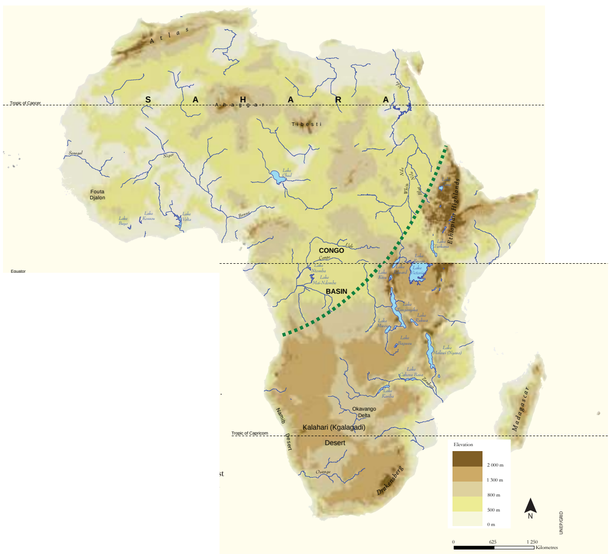
Africa accounts for one-fifth of the Earth's total land area and is the world's second largest continent, covering 30.2 million km^2 and comprising of 54 countries (Sayre, 1999) (See Map 1). Africa is made up of a stunning mosaic of forests and woodlands, mountains, deserts, coastal lands and freshwater ecosystems. With such a diverse range of habitats and a rapidly growing population, the continent is a strategic region in terms of global development opportunities. A broad continental overview of topography, climate, and biodiversity provides valuable context for the implementation of SFiM methodology-based abatement programmes.



Topography

Africa is largely a low-altitude land mass dominated by an uplifted central plateau characterized by vast level plains. Two distinct regions in terms of elevation divide the continent from the Horn of Africa in the northeast, fronting the Great Rift and Ethiopian Highlands, to the coastline of northern Angola in the southwest (Stock, 2004) (See Africa Figure 2). The southeast portion tends to be of higher altitude with plains and plateaus ranging from 1,000 to 2,000 m above sea level, standing out in the landscape (Nyblade and Robinson, 1994).

Figure 2. African Topography



(From UNEP/GRID-Sioux Falls, 2008)

The Sahara Desert in northern Africa is the largest in the world, spanning nine million km^2, and covering almost one-third of the continent. Smaller deserts include the Kalahari, Karoo, and Namib Deserts that form the southern hemispherical counterparts centred on the Tropic of Capricorn. Droughts and fire during the past three decades have caused degradation of land at the desert margins, particularly the Sahara, raising concerns as to desertification of the savanna transition zones between the outlying arid deserts and Africa's wet central rainforests (Herrmann and Hutchinson, 2005).

Mountains rise up across the landscape as scattered exceptions to the lower lying grasslands, savannas, deserts, and forests (UNEP, 2008). The more prominent ranges, from north to south, include: i) the Atlas Mountains, extending northeast to southwest in Morocco and Tunisia, and rising to a maximum height of 4,167m (CIA, 2007); ii) the Ethiopian Highlands, termed the Roof of Africa due to its altitude and extent, located in the Horn of Africa where summits reach heights of up to 4,550 m; and, iii) the Great Rift Valley, a dramatic depression extending from the Red Sea to Mozambique that is fronted by many of Africa's highest mountains including Mount Kilimanjaro (5,895m), Mount Kenya (5,199m) and Mount Margherita (5,109m). Other notable highlands include Mount Cameroon (4,095m) in West Africa and the Drakensberg Mountains (3,482m) in southern Africa.

Even though Africa is the world's second driest continent (after Australia), rivers and lakes still abound (UNEP, 2008). However, freshwater is unevenly distributed, due in large part to the rainfall variability in different climatic zones. Many rivers show dramatic seasonal variability and inter-annual variation (Walling, 1996). Major drainage systems include i) the Nile (6,600 km), the longest river in the world with a catchment of 3 million km^2 covering 10% of Africa ii) the Congo (4,700 km) flowing westwards through central Africa; iii) the Niger River (4,180 km) of West Africa and the continent's third longest; iv) the Zambezi River (2,700 km) that empties into the Indian Ocean; and, v) the Orange River (2,200 km) emptying into the Atlantic.

Largely located in East Africa, the continent has numerous lakes that support important fisheries, providing livelihoods for millions of people andcontributing significantly to the food supply (UNEP, 2006). Among them are: i) Lake Victoria, third largest in the world by area; ii) Lake Tanganyika, third largest by volume; iii) Lake Malawi, third largest within the Great Rift Valley great lakes system, and, iv) Lake Albert, also in the Great Rift Valley (Adams, 1996). Lake Chad is northern Africa's largest lake in terms of area, but it is strikingly shallow, reaching only 10m at its deepest point. Populations surrounding Africa's lakes are extremely high - Lake Victoria has one of the highest population densities in the world (1000 persons / km^2 in parts of Kenya) (UNEP, 2006).

Soils

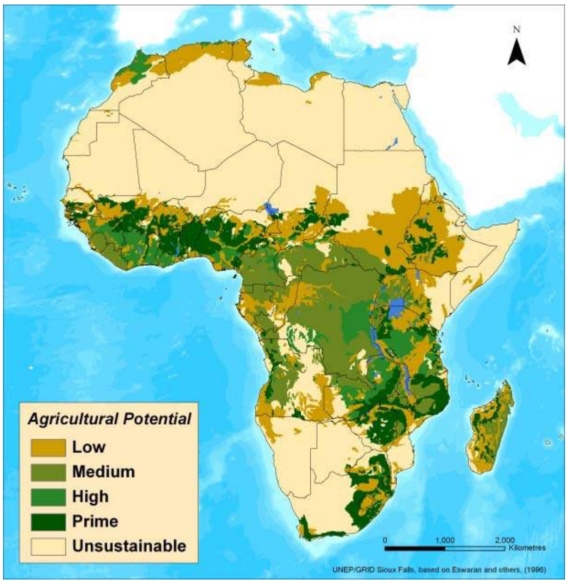
Africa has patches of the most fertile earth in the world, but generally soils are fragile, often lacking in essential nutrients and organic matter. At a continental scale, soil fertility is largely relative to rainfall (Lehman, 2011). At a regional/landscape scale the fertile/infertile division is driven by differences related to landscape position and resulting in local nutrient depletion or enrichment (Scholes *et al.,* 2001).

Africa's soils can be divided into three orders that branch out from the equator: i) Oxisols, older nutrient leached soil found exclusively in low latitudes; ii) Ultisols, red clay soil found in humid to tropical regions with patches of fertility; and, iii) Aridisols, desert soils that rapidly lose nutrients in rainfall and have characteristically low organic matter. Half of available soil is moisture starved and unable to support vegetation. The other half consists of old, highly weathered, acidic soils that contain high levels of iron and aluminium oxides, resulting in the characteristic red-earth Africa is known for (Jones, 2013).

Arable land is not evenly distributed across Africa with over half being either desert or considered too infertile to support agriculture (Eswaran *et al.,* 1996). Since most soils in Africa are weathered, leached of minerals and nutrient-poor, they require significant nutrient inputs for sustainable farming. Soil infertility within these areas limits land use capacities, and shifting cultivation (slash-and-burn), is common-practice (Stock, 2004).

Fertile soils that are better suited for agriculture are located in West Africa (south of the Sahel in Senegal, Mali, Burkina Faso, Ghana, Togo, Benin, Nigeria, and Chad), as well as in South-eastern Africa (Portions of Mozambique, Zambia, Zimbabwe and South Africa) (FAO, 2007) (see Africa Figure 3). Other areas in Africa considered adequate for medium-to-large scale agriculture include portions of: Cote d'Ivoire, southern Ghana, Tanzania, the Democratic Republic of the Congo (DRC), Nigeria, and, to a lesser degree, areas within Zambia and northern Morocco (UNEP, 2008).

Figure 3. African Agricultural Potential



(From UNEP/GRID-Sioux Falls based on Eswaran et al., 1996)

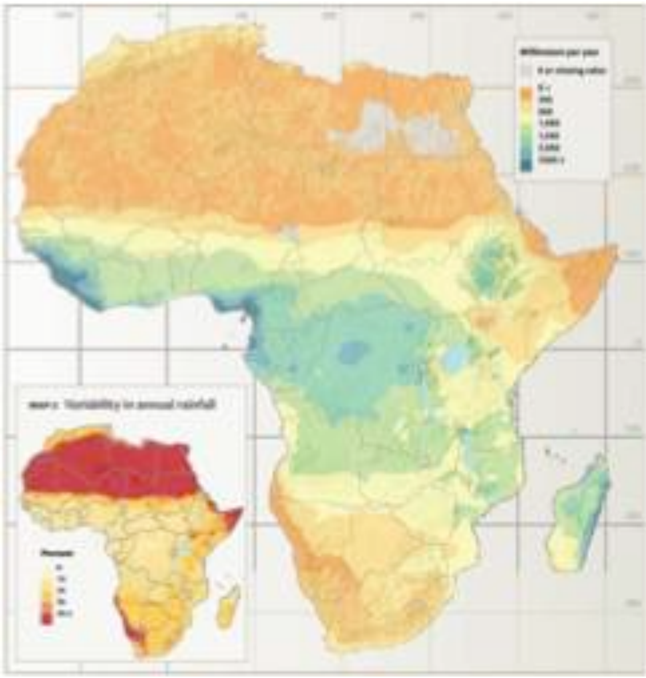
Climate

The continent is divided almost equally by the equator, and does not extend much beyond 35° north or south of it, which is the primary driver for Africa's largely hot tropical climate. The majority of the continent has mean temperatures above 21° C for nine months of the year (Goudie, 1996). In many African regions, both humid and arid conditions are associated with mean maximum temperatures higher than 30°C.

There is a vast amount of inter-annual variation in rainfall with ranges from almost 0 mm in parts of the Sahara to 9,950 mm near Mount Cameroon (Walling, 1996). The primary determinant of precipitation in Africa is the Inter-Tropical Convergence Zone (ITCZ), which consists two high-pressure systems converging on the equator. Two sub-tropical high-pressure belts, commonly referred to as Harmattan in the north and Monsoon in the south, circulate air toward the equator. When they meet, air is forced upward and cooled, forcing atmospheric moisture out as precipitation. The remaining dry air then cycles back toward the subtropics where it descends, producing desert climates at latitudes approximately 20 degrees north and south of the equator (UNEP, 2008).

The ITCZ and its corresponding rain belt distributes most of Africa's rainfall in a fluctuating annual cycle across a latitudinal range north and south of the equator. Precipitation is highest in Central Africa and tends to decrease with an increased distance from the equator (see Africa Figure 4). Dry seasons range from 3 months in the high-rainfall belt near the equator, to 9 months in the subtropical arid zones in the continental interior (Archibald *et al.,* 2010). Moisture availability is largely dependent on rainfall, however, absorption rates of soil and vegetation, the relative position to oceans and lakes, as well as temperature and evapo-transpiration, also play key roles.

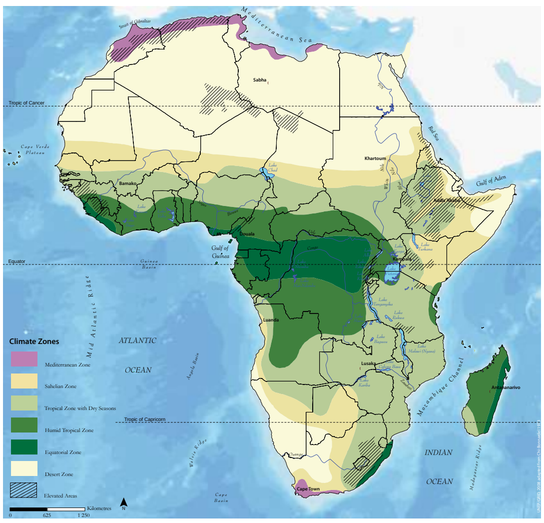
Figure 4. Annual Precipitation



(From WorldClim (Hijmans *et al.,* 2005 – MarkSim (Jones and Thornton 2013)

Collectively, six climate zones are defined in Africa, with a clearly mirrored pattern north and south of the equator following rainfall distribution (see Africa Figure 5). Furthest from the equator lies the Mediterranean Zones, followed by Desert Zones, Sahelian Zones, the Tropical Zone with Dry Seasons, the Humid Tropical Zone and the centrally located Equatorial Zone.

Figure 5. African Climate



(From UNEP/GRID, 2008 adapted from Chi-Bonnardel)

Biomes

Africa accounts for almost one-third of global biodiversity, with the greatest concentrations occurring in the African equatorial ecosystems and those that border them. The African mainland has between 40,000 and 60,000 plant species of which approximately 35,000 are endemic, comprising one-sixth of the world's plant species (Programme U, 2011). Of the world's 4,700 mammal species, one-quarter exist in Africa. It is home to more than 2,000 bird species constitute over one fifth of the world's species, with approximately 1,600 species endemic to sub-Saharan Africa (Programme U, 2011). Southern Africa alone has at least 580 families and about 100,000 known species of insects, spiders, and other arachnids (Anon, 2007).

Biodiversity throughout Africa follows complex patterns determined by climate, geology and evolutionary history (WWF, 2014). Species richness in Africa strongly correlates with climate and moisture availability (amount and timing of rainfall), and the associated amount and nature of vegetation (Stock, 2004). For example, the equatorial centre of Africa is both highest in rainfall and number of species (Meadows, 1996).

Ecoregions (large units of land or water containing a geographically distinct assemblage of species, natural communities, and environmental conditions) are useful for characterizing biodiversity at continental and regional scales (WWF, 2014). Ecoregions are used as a strategic tool to determine conservation investments for the World Bank, the US Agency for International Development, the World Wildlife Fund, the World Resources Institute, The Nature Conservancy, and several foundations (Dinerstein *et al.,* 1995, Roca *et al.,* 1997, Olson and Dinerstein, 1998). The Afrotropical biogeographic realm comprises seven major biomes and numerous terrestrial ecoregions based on White's 1983 widely used vegetation maps (Olson *et al.,* 2001).

Large swathes of Africa's habitats remain intact and include a network of over 3,000 Protected Areas (PAs), including 198 Marine PAs, 50 Biosphere Reserves, and 80 Wetlands of International Importance. Eight of the world's 34 international biodiversity hotspots are in Africa. Despite their recognized status, these areas remain under threat by civil unrest, population encroachment, uncontrolled wildfires, and the introduction of alien species (UNEP, 2008).

Africa's seven Biomes correspond closely with the climate zones and include (see also Map 2):

Mediterranean Forests, Woodlands, and Scrub—Running along the coasts of both northern and southern Africa, these biomes are biologically rich, with several endemic species (Allen, 1996).

Desert and Xeric Shrublands – Deserts are found across much of North Africa and along Namibia's coast, extending slightly into South Africa with Xeric Shrublands existing in the Kalahari, the Karoo, and the Sahel in northern Africa. Desert vegetation is adapted to sparse and unpredictable precipitation, extremes of temperature, and very poor soils (Stock, 2004). The Namib Desert and the Karoo in the west of South Africa have an estimated 4,500 plant species, a third to one-half of which are endemic.

Tropical and Subtropical Grasslands, Savannas, and Shrublands – Savannas are located in a broad band surrounding tropical rainforests and have significant dry seasons. African savannas are home to a greater diversity of large mammals than are found in similar ecosystems on other continents (MacDonald, 2003).

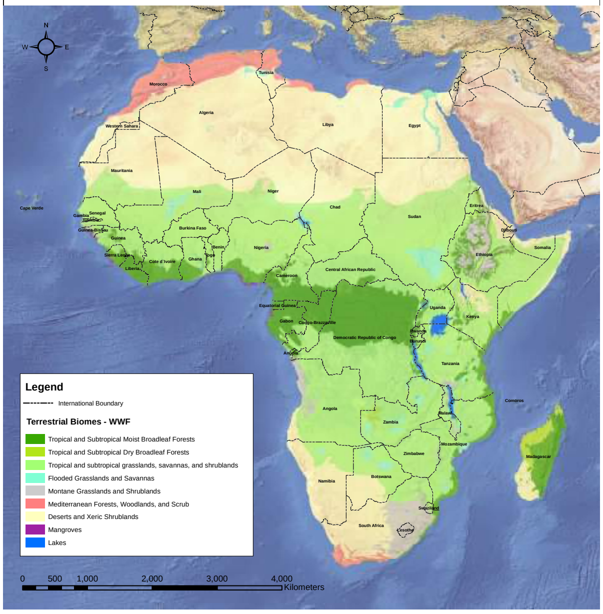
Tropical and Subtropical Moist Broadleaf Forests – Rainforests are located just north and south of the equator, spanning the coastal areas of Sierra Leone to Gabon and inland across most of the DRC's central and northern territories. Rainforest vegetation generally forms in layers, culminating in closed canopies so dense that only a little sunlight reaches the forest floor (MacDonald, 2003).

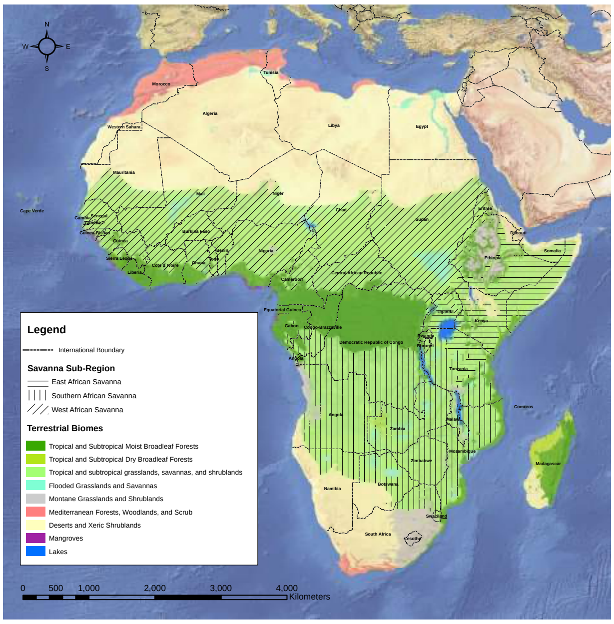
Tropical and Subtropical Dry Broadleaf Forests – Found only in Madagascar, the tropical dry forests in the western part of the island support hundreds of endemic plant and animal species, including numerous chameleons, lemurs and fossas, the world's most endangered tortoise - the Angonoka tortoise, and the rare aye-aye (UNEP, 2008).

Flooded Grasslands and Savannas – Flooded Grasslands are found only in South Africa, where the Drakensberg Mountains and the Great Escarpment create an interior area of high elevation and moderate rainfall (Palmer and Ainslie, 2005). Conversion of large tracts of land to agriculture and livestock production has altered the plant species composition in these areas. Human population is extensive and biodiversity is negatively affected.

Montane Grasslands and Shrubs – Found in relatively isolated areas of high-elevation in the Ethiopian Highlands, the Albertine Rift, and the Arc Mountains of East Africa. The area begins at around 1,000 m and extends to above 3,500 m with various forest, shrub, and grasslands adapted to altitude. There are many endemic species within the montane biome (UNEP, 2008).

Map 2 - Terrestrial Biomes of Africa





African Savannas

Covering half of Africa's land area, savanna is the characteristic ecosystem of the continent extending 25° north and south of the equator (Adams, 1996b; Olsen *et al.*, 2001). Vegetation dominance across Africa's savanna varies spatially and is manifested regionally as mosaics of forest, grassland, woodland, and shrubland within classical open treed grassland (Hill and Hanan, 2010). Categorized as the *Tropical and Subtropical Grasslands, Savannas, and Shrublands Biome* they form a contiguous band around the central rainforests creating a transition zone between dense forests and arid deserts (see Map 2). Over 15 M km^2 in

Africa can be described as savanna (Sayre, 1999), dwarfing the scale of Australia's comparable biome.

The scale and diversity of African savannas present challenges when attempting to broadly define their characteristics, however, comparable environmental conditions to those found in northern Australia certainly exist. Similarities can be observed in topographical make-up (largely occurring on flat landscapes of infertile soils), seasonality (possessing distinct wet/dry seasons), and in temperature (retaining high heat indexes year-round). African savannas occur under more markedly seasonal rainfall conditions than Australian savannas, existing in areas of lower and less seasonal rainfall due to higher soil fertility (Lehmann *et al.,* 2011).

Tree cover ranges between 8 to 40 % from African savannas to wooded-savanna mosaics, with trees existing at various densities within landscapes, depending on local conditions (Hill and Hanan, 2010). The heterogeneous nature of savanna landscapes is encouraged by a variation in climate, soil, topography, atmospheric CO_2, fire, browsers, grazers, and human interaction (Beerling and Osborne, 2006; van Langevelde *et al.,* 2003; Du Toit and Cumming, 1999). Complex interactions between these known drivers dictate structural and functional capacities at landscape scales.

Importantly, Australian and African savannas are characterized as fire-dependent ecosystems, with their ecological processes, structure and species composition having evolved with, and inextricably linked to, fire activity (Hardesty *et al.,* 2005). Fire regimes maintain their characteristic form and function, and the species they contain are highly adapted to regular fire events (Bond, 1997).

To enable broad regional assessment and comparison with northern Australian savannas, three savanna sub-regions (East, Southern and West African) have been defined based on geographical, climatic and compositional similarities.

Savanna Climate

Savannas occur across three African climate zones with the Tropical Zone with Dry Seasons the most comparable to northern Australia's. This climate dominates the Southern African Savanna Sub-Region and a considerable proportion of the West African Sub-Region.

<u>Humid Tropical Zone</u>

The Humid Tropical Zone exhibits peaks in precipitation and a short dry season. Some areas in this zone (East Africa) experience two rainfall maxima; the first occurs as weather systems associated with ITCZ migrate toward higher latitudes, while a second occurs as those weather systems move back toward the equator and the lower latitudes (Stock, 2004). The average annual rainfall generally ranges between 1,100 mm and 1,800 mm

(FAO, 2001). Temperatures are relatively high, although with somewhat more seasonal variation than the Equatorial Zone.

Sahelian Zone

Only about 250 to 500 mm of rain falls in the Sahelian climate zone (Stock, 2004; FAO, 2001). With considerable seasonal and inter-annual variation in rainfall, the potential for rain-fed agriculture is very low (IWMI, 2001). Average annual temperatures in areas adjacent to the Sahara and in the Horn of Africa range from 26° to 29° Celsius, while somewhat cooler temperatures in elevated areas adjacent to the Namib Desert are several degrees cooler (CRES, 2002).

Tropical Zone with Dry Seasons

To the north and south of the Humid Tropical Climate Zone are mirrored zones of tropical climates with distinct wet seasons followed by long dry seasons, where precipitation and temperature are more seasonal (Goudie, 1996). Here, dry seasons last more than six months and tend to increase in length with distance from the equator. Annual average precipitation is generally 600 to 1,200 mm (FAO, 2001), with pronounced inter-annual variation. Both annual and daily temperatures vary more here than in the climate zones closer to the equator (Stock, 2004).

Savanna Structure and Function

African savannas are commonly divided into wetter, nutrient-poor savannas growing on infertile soils and drier nutrient-rich savannas growing on fertile soils. High mammalian and insect herbivore populations of fertile savannas consume fuel loads and subsequently reduce fire frequency. In the West African Sub-region, the role of domestic animals and low rainfall explain savanna vegetation patterns - in East Africa wild ungulate's migratory patterns are considered crucial elements, and, in Southern African savannas, research has emphasized fire as a main savanna structural driver.

Methodology-based SFiM is theoretically possible in any African Savanna, however, the Southern African Savanna exhibit characteristics, in terms of their structure and function, more comparable to the Australian setting.

Structure and Function

Savannas are predominantly comprised of grasses, intermixed with woody species (shrubs and trees) that are articulated in varying densities across landscapes (Bond, 2008; Lehmann, *et al.* 2009). The primary vegetative expressions of savannas are the more or less continuous coverage of C4 grasses that are tolerant to drought and thrive in intense sunlight, and tree cover that does not form a closed canopy (Adams, 1996b). Wet seasons produce abundant fire fuels and dry seasons create conditions that lead fuel curing and frequent fires. The fires kill many shrub and tree seedlings before they are large enough to survive the flames, thus savanna favours C4 grasses that can quickly regenerate (Adams, 1996b).

Structural drivers, which determine woody coverage, include environmental factors such as climate, topography, moisture availability and soil composition, as well as natural episodic events such as fire, human interaction, and herbivory (Hanan *et al.,* 2008). External drivers. External drivers (primarily climate and topography) are typically similar, since savannas thrive under comparable conditions worldwide. However, internal factors can be very different, even within landscape-scales. While ecologists still deviate over the relative importance of each variable, most savanna researchers acknowledge these four internal factors (soil moisture and nutrient status, herbivory, human interaction, and fire), as the most important influencers of regional structural variations within savannas (Frost *et al.,* 1986; Solbrig *et al.,* 1996; Scholes and Archer, 1997).

What is now known as the 'classical model' of savanna structure was based on the premise that soil water alone was the primary driver, which mediated the equilibrium between the tree and grass species (Walter, 1971). Several subsequent models employed this two-layer proposal as a basis to explain shifts in trees and grasses in savannas (Walker *et al.*, 1981; van Langevelde *et al.*, 2003). However, this simplified model has recently come under increasing criticism, with critics insisting the classic model is incapable of accounting for the sheer diversity of environments where savannas are encountered (Scholes and Archer, 1997; Higgins *et al.,* 2000; Jeltsch *et al.,* 2000; Sankaran *et al.,* 2004; Bond, 2008).

As a response to criticisms of the two-layer hypothesis, new explanations that recognise the fundamental role of episodic events in maintaining the coexistence of trees and grasses have been proposed (Menaut *et al.,* 1990; Jeltsch *et al.,* 1996, 1998, 2000; Higgins *et al.*, 2000; van Wijk and Rodriguez-Iturbe, 2002; Gardner, 2006). These new explanations suggest that the impact of drought and defoliation, caused by fire and herbivory, varies depending on the life-history stage of affected vegetation. This causes demographic bottlenecks on tree recruitment and the repetition of these negative impacts on tree reproduction create opportunities for the establishment of grasses (Warner and Chesson, 1985).

In this more complex model of explanation, water supply, and subsequently soil nutrients, are the primary drivers of species persistence or suppression in drier areas (Jeltsch *et al.,* 1996, 1998; Higgins *et al.,* 2000; van Wijk and Rodriguez-Iturbe 2002), whereas herbivory and fire limit tree-dominance in humid areas (van Langevelde *et al.,* 2003; Bond, 2008; Scheiter and Higgins, 2007).

Variation between drivers in terms of their relative location can clearly be seen in sub-regional interpretations of local drivers within savanna structure. For example, in the West African sub-region, the role of domestic animals and the inverse relationship between nutrients and rainfall are used to explain patterns in savanna vegetation type (Menaut and Cesar, 1982; Hanan *et al.*, 1991). In East Africa the role of wild ungulate's migratory patterns and the presence of soil macronutrients (N, Ca, K, P) on herbivore behaviour are considered crucial elements of structure (McNaughton, 1983; 1988; McNaughton and Banyikwa, 1995). In southern African savannas, research has emphasized fire as a main savanna structural driver (Scholes and Walker, 1993).

Fertility

Ecologists commonly divide savannas into wetter nutrient-poor (dystrophic) savannas growing on infertile soils, and drier, nutrient-rich (eutrophic) savannas, growing on fertile soils (Bell, 1982, Huntley, 1982). In Africa broad-leafed plants typically dominate the infertile savannas, while fine-leaf species thrive in the fertile zones (Robertson, 2005). Differences between the carbon and nitrogen cycling determine that infertile savannas have a high carbon to nitrogen ratio (C:N ratio) and sustain relatively low mammalian and insect herbivore populations compared to fertile savannas (Scholes and Archer, 1997).

As a result, low herbivory in the infertile savannas increases fuel-load, the main determinant of fire behaviour (Gambiza *et al*., 2005), which increases volatilization and loss of nitrogen to the atmosphere, reduces build-up of organic matter in the soil, and promotes the infertile condition (Hill and Hanan, 2010). Higher grazing and browsing intensity in fertile savannas reduces fuel-loads and promotes recycling of nitrogen, thus propagating its fertile condition.

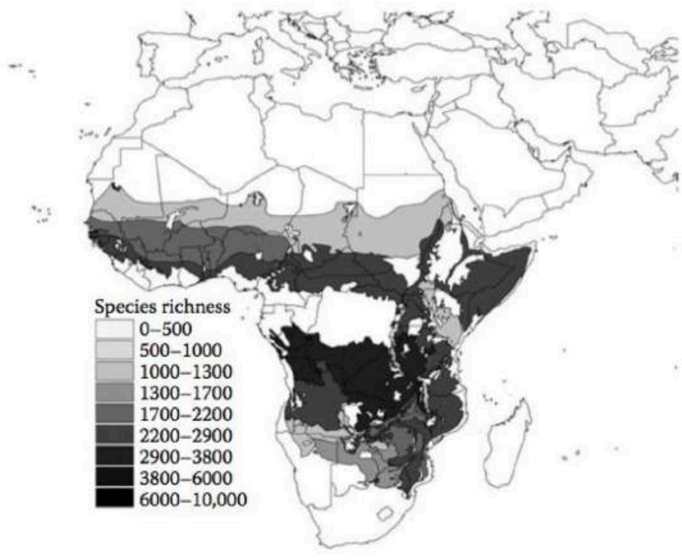
Fertile savannas also support larger human populations, which are an important savanna determinant, particularly through land use pressures associated with increased agriculture, livestock density and natural product harvesting.

Biodiversity

Africa's Savanna Biome has been the centre of evolution to many of the most charismatic large mammal groups on Earth. The savannas are home to lions, leopards, cheetahs, hyenas, and the African Wild Dog as well as elephants, rhinoceros, hippopotamus, crocodiles, and an assortment of wild ungulates. They support a higher diversity of ungulate than any other biome or continent. This exceptional faunal diversity is directly linked to the high spatial heterogeneity of African savanna ecosystems. The biomass densities of herbivores in certain protected savanna ecosystems account for some of the highest levels of herbivory ever quantified in terrestrial ecosystems (Botkin *et al.,* 1981; McNaughton and Georgiadis,1986).

Species richness of vascular plants (see Africa Figure 6; Kier *et al.,* 2005) shows most savanna ecoregions as having in excess of 1,000 plant species. The Central Zambezian Miombo Woodlands exhibits the highest plant species richness in Africa (3,800).

Figure 6. Plant Species Richness



(from Kier *et al.,* 2005)

In general, West African savannas exhibit lower biodiversity and possess relatively few endemic animal species. Western savannas have been greatly reduced, degraded and fragmented by agricultural activities, uncontrolled fire, and clearance for wood and charcoal. Although many protected areas exist, most are under-resourced "paper parks" with little active enforcement on the ground. Over-hunting has decimated most of the larger mammal species, and there is a large number of species in the West African savanna ecoregions that are threatened with extinction (WWF, 2014b). For example, West African subspecies of giant eland (*Taurotragus derbianus derbianus*) and wild dog (*Lycaon pictus*) persist in only small numbers in scattered populations in the savanna woodlands. The same can be said for the lion (*Panthera leo*), leopard (*Panthera pardus*) and cheetah (*Acinonyx jubatus*). West African populations of elephant (*Loxodonta africana*) and western giraffe (*Giraffa camelopardalis peralta*) are also extremely small, but of great conservation interest for maintaining the ecotourism potential of the fragile sub-regional protected area systems. Roan antelope (*Hippotragus equinus*) and West African savanna buffalo (*Syncerus caffer brachyceros*) are also mostly restricted to protected areas that are considered under threat. Western savannas correspond with part of the Sudanian regional centre of endemism, which has more than 1000 endemic plants (WWF, 2014b).

In East Africa, the Horn of Africa Acacia savannas have been identified by the WWF as 1 of 34 global biodiversity hotspots. To qualify as a hotspot, a region must contain at least 1,500 species of vascular plants (> 0.5 % of the world's total) as endemics, and it must have lost at least 70% of its original habitat (UNEP, 2008). The Horn of Africa is one of the two entirely arid savanna hotspots, and is renowned for its biological resources. Endemic birds include degodi lark (*Mirafra degodiensis*), short-billed crombec (*Sylvietta philippae*), and bulo burti bush-shrike (*Laniarius liberatus*). Mammals endemic to this region include the African wild ass (*Equus africanus somaliensis*), Speke's gazelle (*Gazella spekei*), hirola (*Damaliscus hunteri*), dibatag (*Ammodorcus clarkei*), Grevy's zebra (*Equus grevyi*), naked mole rat (*Heterocephalus glaber*), and Hunter's hartebeest (*Damaliscus hunteri*). It also has Africa's highest number of endemic reptiles and a number of endemic and threatened antelope (WWF, 2014b).

Huge populations of mammals are only found in the eastern and southern savannas, including at least 79 species of antelope (UNEP and McGinley, 2007). Southern African savannas exhibit mixes of miombo, mopane, acacia and smaller wetlands that provide habitat for a wider variety of animals, including endangered and charismatic mammals such as African elephants (*Loxodonta africana*) and black rhinos (*Diceros bicornis*). In southern Africa the Central Zambezian Miombo woodlands (located in Zambia, the DRC, and Tanzania) is a centre of bird diversity and has a high degree of floral richness when compared to the other savanna ecoregions. Although as a whole it has a fairly low degree of generic endemism, sharing many species with the Sudanian and coastal formations, species richness and localized endemism is still high in many herbaceous plant genera such as *Crotalaria* and *Indigofera*. Furthermore, this ecoregion is the centre of endemism for the *Brachystegia* genus with 17 of its 35 species located in Zambia.

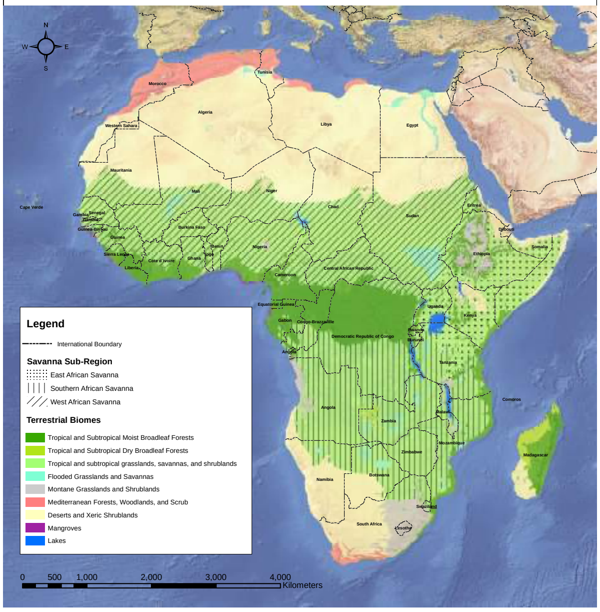
Africa has over 2 million km² of PAs (an area four times the size of Spain) (IUCN-WCPA, 2014). The ecoregions under the best protection tend to be the savanna habitats, particularly those of eastern and southern Africa (Burgess *et al.,* 2004). However, better coverage in southern African PA systems exists for compelling animals, such as elephant, lions, and rhinos (de Klerk *et al.,* 2004, Fjeldsa *et al.,* 2004).

Savanna Sub-Regions

Within the Tropical and Subtropical Grasslands, Savannas, and Shrublands Biome there exists 20 ecoregions ranging from tropical to temperate savannas, with boundaries for phytogeography based on White's 1983 widely used vegetation maps (Olson *et al.,* 2001).

These have been divided into three sub-regions to streamline regional assessment (See Map 3). Sub-regions were grouped based on compositional, climatic, and geographical similarities, allowing for broad regional comparison to Australian savanna conditions.

Map 3 - African Savanna Sub-Regions



East African Savanna Sub-region

The East African Savanna sub-region include portions of 10 countries from northern, central, and south-eastern Africa, including: South Sudan, Uganda, Eritrea, Ethiopia, Somalia, Uganda, Tanzania, Rwanda, Burundi, and much of lowland Kenya.

The East African sub-region includes 4 savanna ecoregions: The Northern Acacia–Commiphora bushland and thicket, Southern Acacia–Commiphora bushland and thicket, Somali Acacia–Commiphora bushland and thicket, and the Victoria Basin forest–savanna mosaic. Characteristics include:

- Topography – situated on the slopes of the Central African Plateau and inclines upward from east to west.
- Soil – Higher fertility levels.
- Scale – Approximately 3 M km^{2}.
- Climate – Sahelian and Tropical Zone with Dry Seasons.
- Rainfall – Mean annual rainfall ranges from 600 mm to 800 mm, but extremes exist from as low as 200 mm to as high 1200 mm.
- Seasonality – Dual wet and dry seasons.
- Human Interaction – High level of human interaction.

Temperatures are high and climate ranges from Sahelian to Tropical Zones with Dry Seasons, which bear similarities to Australian conditions, however, savannas exist in much lower rainfall gradients. Ranging from 200 mm in the drier areas to about 1200 mm closer to the Ethiopian Highlands and, unlike Australia, falls bi-annually, with dry periods in between. Most precipitation falls during the long rains, typically from March to June, and less falling in the short rains of October to December. The timing and amounts of rainfall vary greatly from year to year, and it is fairly common for one of the rainy seasons to fail entirely.

Savanna vegetation is generally comprised of semi-arid mixed woodland, scrub and grassland located on plains or plateaus with comparatively more fertile soils than Australia.

Southern African Savanna Sub-Region

The Southern African Savanna Sub-Region is the second-largest of the three sub-regions and includes portions of 16 countries including: Angola, Botswana, Burundi, Democratic Republic of Congo, Lesotho, Madagascar, Malawi, Mozambique, Namibia, Republic of Congo, Rwanda, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe.

The southern Africa savanna sub-region is comprised of 11 savanna ecoregions including: The Angolan Miombo woodlands, Angolan Mopane woodlands, Central Zambezian Miombo woodlands, Eastern Miombo woodlands, Southern Miombo Woodlands, Southern Congolian forest–savanna mosaic, West Congolian forest–savanna mosaic, Kalahari Acacia–Baikiaea woodlands, Southern African bushveld, Zambezian Baikiaea woodlands, and the Zambezian and Mopane woodlands. Characteristics include:

- Topography – Relatively flat atop the Central African Plateau.
- Soil – Vast areas of infertile soils with some highly fertile areas.
- Scale – Approximately 5 M $km^{2.}$
- Climate – Sahelian, Tropical Zone with Dry Seasons, and Humid Tropical Zone.
- Rainfall – Mean annual rainfall ranges from 600 mm to 800 mm but extremes exist from as low as 200 mm to as high 1500 mm.
- Seasonality – Distinct wet and dry season.
- Human Interaction – Vast areas with lower levels of human interaction.

The southern African sub-region encompasses twice as many savanna ecoregions as West and East Africa and expresses more extreme ranges. Elevation can be as low as 200 m in parts of the Southern Miombo ecoregion to as high as 2,000 m in the Southern African bushveld, still most southern African savannas lie on flat surfaces atop the central African plateau with elevation ranging between 800 m to 1,000 m above sea level. The region experiences a tropical climate consisting of Sahelian, Tropical with Dry Season, and Humid Tropical zones and rainfall falls primarily in summer. Rainfall increases, and temperatures decrease, with decreasing latitude and increasing elevation.

Distinct wet and dry seasons exist with mean annual rainfall ranges from less than 200 mm in the south to about 1,500 mm in the north (Southern Congolian forest-savanna mosaic) and temperatures can get as low as –3° C in parts of the bushveld to over 40° C near desert transition zones, however mean maximum temperatures are generally around 27° to 30° C and minimum temperatures rarely get below 9° C (near the coastal areas).

West African Savanna Sub-Region

The West African savanna sub-region is the largest area in consideration, encompassing portions of 22 central and northern African countries including: Chad, The Central African Republic, Sudan, Eritrea, Ethiopia, Uganda, Nigeria, Mauritania, Mali, Benin, Burkina Faso, Togo, Ghana, Côte d'Ivoire, Guinea, Sierra Leone, Guinea-Bissau, Gambia, Senegal, northern DRC and Cameroon.

It encompasses five savanna ecoregions: The East Sudanian savanna, Guinean forest–savanna mosaic, Northern Congolian forest–savanna mosaic, Sahelian Acacia savanna, and West Sudanian savanna. Characteristics include:

- Topography – Flat.
- Soil – Vast ranges of fertile intermixed with sandy infertile soils.
- Scale – Approximately 7 M Km^{2}.
- Climate – Sahelian, Tropical Zone with Dry Seasons, and Humid Tropical Zone.
- Rainfall – Mean annual rainfall ranges from 600 mm to 800 mm, but extremes exist from as low as 200 mm to as high as 1600 mm.
- Seasonality – Distinct wet and dry season.
- Human Interaction – High level of human interaction.

The sub-region is mainly flat and lies between 200 and 400 m in elevation with very few prominent topographical features. Temperatures range from 18° C to as high as 36° C in parts of the Sahel. The climate is tropical and strongly seasonal ranging from the Sahelian zone in the north and transitioning to Humid Tropical zone in the southern reaches of the Guinean forest-savanna mosaic Ecoregion, with most of the region encompassed by the Tropical Zone with Dry Seasons.

Annual rainfall can be as high as 1,600 mm in the southern portions, but declines in the north, with only 200 mm found on the border of the Sahara. Rainfall is highly seasonal: the dry season can last for several months, during which time most trees lose their leaves and the grasses dry up and may burn. Most rain falls in the summer months of May to September, followed by a 6 to 8 month dry season.

The movements of the ITCZ determine the quantity of rainfall in a particular year. If it penetrates far to the north there will be a long rainy season and good rains if not then the rains may fail totally. During the winter, hot dry winds (known in much of West Africa as the Harmattan) blow from the north, often bringing dust and sand from the Sahara with them.

African Savanna People

Anthropogenic fires have been critical in shaping the vegetation diversity, abundance, and distribution of southern African savannas over the last 1.5 million years (Hall, 1984, Brain and Sillen, 1988, Bond *et al.,* 2005). The five distinct ethnic groups originating within African savannas all evolved in comparable environments and developed markedly similar traditional fire knowledge (TFK) to manipulate savanna landscapes. Application of small fires throughout the dry season typically created a seasonal mosaic landscape, annually re-created by people, consisting of unburned, early-burned, and recently burned patches.

TFK remains largely intact in the more remote African settings and continues today in the form of traditional burning to support contemporary rural livelihoods of many African people. Traditional burning is most important and frequently used to support subsistence livelihoods of remote communities and includes slash-and-burn agriculture, livestock grazing improvements, charcoal production, natural product harvesting, pest control, hunting and reducing wildfire threats.

Africa is the second most populous continent in the world and rural population densities are generally much higher than in the northern Australia savanna setting, typically as low as <1 person km^2. The East and West African Savanna sub-regions are relatively fertile and support very high population densities often upwards of 50 persons km^2. In contrast, the Southern African Savanna Sub-Region is largely infertile and population densities rarely exceed 20 persons / km^2 with large areas supporting considerably less.

In the East African Savanna sub-region subsistence livelihoods, including nomadic pastoralism, are rapidly shifting to smallholder and industrialized agricultural livelihoods. The low rainfall (600 – 800 mm p.a.) and associated limitation in agricultural production have largely been overcome by government irrigation schemes. Large and small-scale commercial farms have transformed the more fertile areas, and smallholder agriculture is increasing in all available areas. Most lands outside of PAs have high human interaction and overgrazing by domestic livestock has led to habitat fragmentation, increased land degradation and desertification in some parts.

In the West African Savanna Sub-Region large expanses of fertile savannas support high population densities and in most areas intensive pastoralism or large-scale commercial agricultural endeavours are common. Rapid population growth and increased land use pressures are leading to rapid conversion of marginal infertile lands for smallholder agriculture livelihoods with individualized land title. Many countries have suffered decades of land-based conflicts, political instability, civil unrest and armed insurgencies. Security of land tenure is often compromised and although numerous PAs exist, most are under-resourced 'paper parks' with little active enforcement.

In the Southern African Savanna sub-region subsistence livelihoods on communal lands are widespread throughout the vast areas of infertile savannas in the higher rainfall area to the north. Lower population densities and less land use pressure, particularly cattle, exist in the central and northern areas due to nutrient-poor soils that limit agricultural potential and widespread presence of tsetse fly (*Glossina spp*.). These remote landscapes support a substantial PA network providing the foundation of biodiversity conservation throughout a largely intact landscape comparable to the northern Australian setting. The more arid fertile soils in the sub-region's southern savannas support higher populations and land conversion and therefore tend to be highly fragmented and more comparable to the East and West sub-regions.

Indigenous Savanna People

Over the course of millennia, savanna people have accrued a vast amount of subsistence ecological knowledge garnered through long-term observation and application within their ancestral home ranges. It is widely accepted that Indigenous peoples created some of the savannas around the world today by burning forests and woodlands (Dublin, 1995). The Eastern Miombo wooded-savannas of Tanzania are one such example (WWF, 2014b).

Africa has a plethora of ethnic groups that originated in the savanna landscape and these are discussed in terms of language family origins (see Africa Figure 7). Historically, there were five distinct language families that originated within Africa's savanna biome. They including: The Afro-Asiatic family (northern savannas in East and West Africa), the Niger-Congo (West African savannas), the Niger-Congo Bantu (spanning western, eastern and southern savannas), the Nilo-Saharan (confined largely to the Sahel and pockets of East African savannas) and the Khoi-san (southern Africa savannas). Each of these language families encompasses a variety of ethnic groups and sub-languages but never-the-less form the basis for broad indigenous comparisons.

Figure. 7 Language Familes of Africa

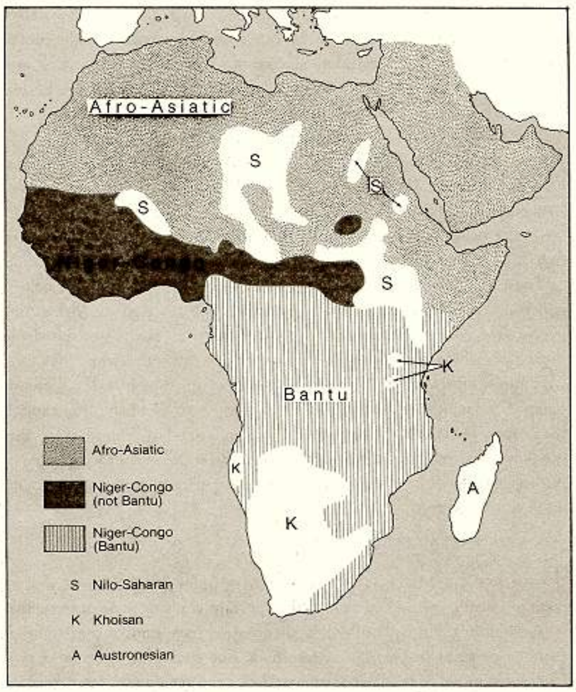


Figure 19.2. Language families of Africa.

(Diamond, 1998: Figure 19.2 p. 382)

Since colonialism, nearly all African peoples can be considered "indigenous" in the sense that they have originated from Africa and nowhere else However, in practice identifying an indigenous group in the modern application is more restrictive (IPACC, 2010). Additional prerequisites of marginalization from majority groups, cultural distinctness, and a strong tie to perceived homelands are important. Not every African ethnic group claims identification under these terms. Groups and communities who do claim such status are often those, who through various circumstances, have been placed outside of the dominant state systems. Their traditional practices and land claims often come into conflict with the objectives and policies preferred by governments, companies and surrounding dominant societies. Identifying a group as indigenous to site-specific areas, such a national park within an African country, can be a complicated endeavour made more so by a long history of ethnic migration, conflict, and colonial restructuring.

Fortunately, whether a group is identified as indigenous to an area based on modern definitions is not a prerequisite to feasibility. This is because it is not the 'original' or 'marginalized' status of the Aboriginal peoples that defined their participation in Australia, but rather their accrued ancestral knowledge of savannas and their intimate understanding and modern desire to use fire within that system.

In Africa, fire knowledge is not the sole proprietorship of one group. As savannas exist across the entirety of the continent, spanning large swaths of both northern and southern hemispheres, many groups utilized fire as land management tool. Whether people originated in the savannas of West Africa and migrated South over the centuries, such as the Bantu pastoralists, or whether they remained in the savannas of their ancestor's birth, such as the San, is irrelevant as both groups would have accrued similar fire strategies to manipulate the landscape. Albeit for differing purposes based on preferred livelihoods, their methods would have been identical, producing similar heterogeneous landscapes from early season burning (Lairs, 2002; Shaffer, 2010; Myers, 2007).

By focusing on savanna people's shared fire-knowledge base in Africa, it negates the often contentious question of 'which group was here first' or 'who is dominant or marginalized in this boundary?' to the less provocative and more project-relevant question of 'where is TFK still practiced and desired and by whom?' The answer to this question leads to the more remote areas of the continent where modern subsistence livelihoods largely mirror traditional livelihoods and the tactics employed today are similar to those of their ancestors. By proxy of being on the fringe of habitable environments, people that reside in remote areas are often indigenous in the entirety of the modern definition (IWGIA undated).

While regional arguments can be made that one group is 'more' indigenous than the other, based on migration patterns and the 'first come' philosophy, on a savanna landscape scale (continental) this distinction is irrelevant as they all evolved within Africa's vast savanna biome and incorporated fire into their daily lives. The various family groups from different areas, evolved in similar ecological environments and as such developed markedly similar savanna-based knowledge reservoirs with which they subsisted.

Traditional Fire Knowledge

Anthropogenic fires have been critical in shaping the vegetation diversity, abundance, and distribution of southern African savannas over the last 1.5 million years (Hall 1984, Brain and Sillen 1988, Bond *et al.* 2005). Evidence from elemental carbon abundance records indicates that humans have had significant control over fire regimes and biomass burning in sub-Saharan Africa since the start of the Holocene approximately 400 000 years ago (Bird and Cali, 1998).

Traditional knowledge (TK) is a knowledge-practice-belief system based on long-term, cumulative observations and interactions by people with the surrounding landscape (Berkes, 1999; Berkes *et al.* 2000). TFK is the cumulative knowledge of traditional burning that is still passed down using stories, songs, artwork, and religious practices and remains largely intact, particularly the reasons for burning (Walters 2010; Shaffer 2010).

Fire has been used in traditional and indigenous management systems to control parasites, stimulate new growth that is palatable to all grazers, prevent bush encroachment, cultivate populations of key resource species of flora and fauna, and presere long unburned areas (Belsky, 1992; Angassa and Baars, 2000; Cauldwell and Zieger, 2000; Driscoll 2010).

Recent studies and historical analysis highlight that indigenous fire management practices in various savanna environments have historically created a mosaic burn pattern, which prevented large conflagrations (Pyne, 1990; Braithwaite, 1996; Mistry, 2005; Kull 2002; Laris 2002 and Eriksen, 2007). Application was likely continuous throughout the dry season and linked to specific livelihood activities with burning for hunting and gathering occurring at anytime. Agriculture and pastoral burning occurred at both the beginning and end of the dry season (Shaffer 2010). The progression of small fires throughout the dry season created a seasonal mosaic landscape that is annually re-created by people, which contains patches of unburned, early-burned, and recently-burned vegetation (Butz, 2009; Laris, 2002).

Historically, the use of fire in Africa was controlled by Traditional Authorities (TA), most likely a land chief, who restricted its use to certain organized events, such as hunting or for religious and cultural occasions. The authority of the chief was seen as part of a religious system where land fertility was guaranteed via rituals tied to the adherence of proper burning procedures. The fires under the land-chief system were regulated, annual, dry season occurrences conducted by the community (Walters, 2010).

TFK within remote rural communities contain information about local adaptive fire management, recent human influences to landscape patterns, and low-cost wildfire control practices that benefit livelihood and biodiversity activities (Shaffer, 2010).

Traditional Burning and Livelihoods

In African savannas the vast majority of land is still held under customary tenure although the proportion of land held in individualized title of some form or other (not necessarily ownership) is increasing (UN-HABITAT, 2005). Most customary land is held in-trust by national governments for community use and access rights are often maintained through local-level governing structures (i.e. TAs). In area's of high population, such as large portions of East and West Africa, communal land is sometimes restructured for settlements or for other more perceived valuable uses (Behnke, 2008). In African countries, attitudes towards land tenure are undergoing a dynamic process of evolution. This process is particularly complex, as customary attitudes, rules, and practices are adapted to fit within the more 'modern' tenure laws that were either inherited from colonial administrations or enacted since independence.

Agriculture is the backbone of the African economy and is the main means of subsistence for rural livelihoods today (Whiteside, 2011). It is estimated that 90% of Africa's population depends on rain-fed crop production and pastoralism, activities largely carried out within Africa's savanna ecoregions (IPCC, 2007).

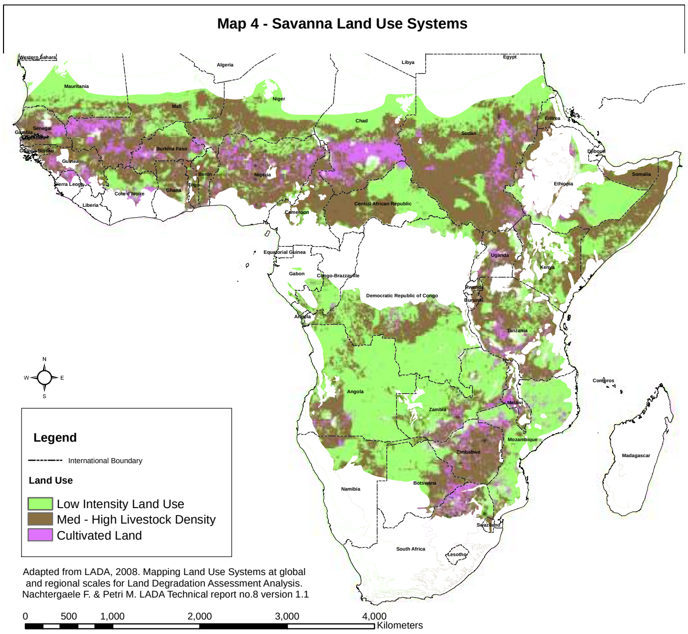
Associated with this process of land tenure change is a shift in land use intensity, practices, and available livelihood opportunities (See Map 4). Three broad rural livelihood profiles exist in Africa based on access to assets (including both material and social resources) and capacity to combine them into livelihood strategies for a means of living. They include:

i. Subsistence Livelihoods;

ii. Smallholder Agricultural Livelihoods; and

iii. Industrialized Agricultural Livelihoods.

TFK and practices are remarkably similar throughout Africa and communities continue to employ traditional burning to manage natural resources necessary for daily livelihood activities. This includes slash-and-burn agriculture, burning pasture to improve grazing, charcoal production, natural product harvesting, controlling pests, hunting, and reducing wildfire threats (Kepe and Scoones, 1999; Kull, 2002; Kepe, 2005; Sheuyange *et al.,* 2005). The importance of TFK and level of traditional burning implemented to support the three livelihood opportunities vary.



Map 4 - Savanna Land Use Systems

Subsistence Livelihoods

Subsistence livelihoods represent the vast majority of livelihoods on customary land tenures, particularly in the more remote rural settings within infertile savannas. Land use is based on traditional farming practices of small-scale agriculture (labour intensive, rain-fed or wetland crops), livestock production (grazing of communal lands) and natural product harvesting. Land use intensity to support household level subsistence is typically low and the sale of surplus crops, livestock and natural products (i.e. thatching grass) provides approximately 20% of disposable income for rural Africans (Jones, 2008; SADC, 2010). Rights and access to resources are commonly held, resulting in low economy livelihood opportunities with a high dependence on natural resources that are inherently vulnerable to natural disasters, such as drought and wildfires.

With limited access to human capital (education, healthcare), natural resources (land), financial capital (loans and credit) and infrastructure (roads to markets) TFK is very important to support subsistence livelihoods. Traditional burning remains the most frequently and widely used, and arguably the only, land management tool available to communities in these settings. Slash-and-burn agriculture, burning for pasture management and charcoal production provides the foundation of most subsistence livelihoods in African savannas.

Smallholder Agricultural Livelihoods

Smallholder Agricultural Livelihoods are associated with land held in individualized title of some form typically in the more fertile areas of the savannas and/or areas of high land use pressure. Land use remains based on traditional agro-pastoral farming practices combined with more contemporary farming systems. Intensity-of-use is medium to high and oriented toward commercial production systems.

Individualized land access and rights enable higher economy livelihood opportunities with less reliance of TFK to support smallholder livelihood farming practices. Traditional burning remains important. However the commercial valorisation of natural resources dictates that landowners are less tolerant of fire. Improved access to capital enables more intensive land management practices and control of fire resulting in less frequent use of traditional burning to support smallholder livelihoods.

Industrialized Agricultural Livelihoods

Industrialized Agricultural Livelihoods in Africa are associated with individualized land title, lease or freehold, and are limited to relatively isolated pockets of moderately fertile soils, such as floodplains. Land use is characterized by commercial irrigated crop production and high intensity cattle production. Infertile soils and low crop yields limit the viability of industrialized commercial agriculture of most forms. Long distances to potential markets and high transportation costs limit the competitive ability of produce and many large-scale developments are politically motivated, poorly planned and unsuccessful. Food supplements, except crop residues, are not provided and only basic veterinary services are provided by the national governments resulting in limited commercial cattle ranching (Robertson, 2005).

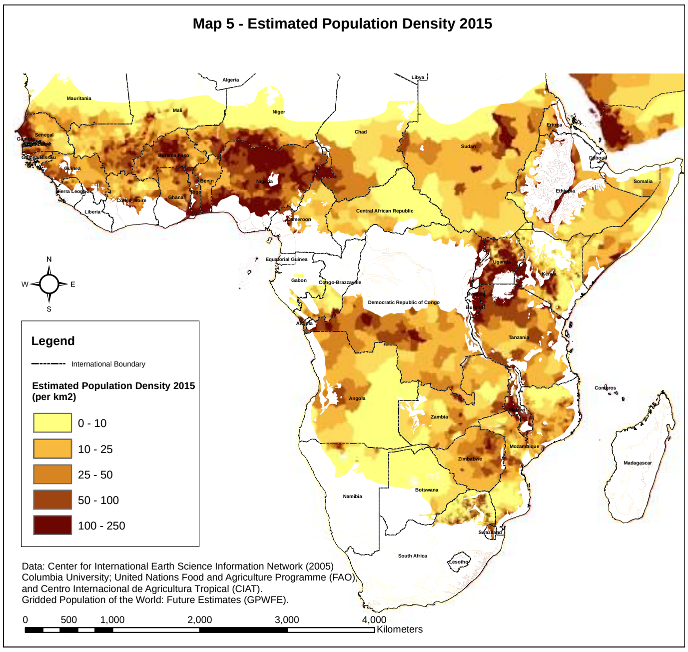
Industrialized agricultural practices significantly modify natural land cover and are generally independent/intolerant of fire use as a resource management tool.

Land degradation by overgrazing and intensive agriculture on marginal lands, commonly associated with Smallholder and Industrialized Agricultural Livelihoods, is a major driver of land-cover change and is unsustainable.

Population

Africa is the second most populous continent in the world with the fastest growing population. As of 2014, an estimated 920 million people inhabit Sub-Saharan Africa with over 60 % living a rural existence (PRB, 2014). The majority inhabit East and West Africa with populations of 339 and 378 million, respectively, whereas southern Africa has the lowest regional population at 61 million (PRB, 2014). In contrast, only 30% of Australia's 23.5 million people live in rural settings where densities rarely cap 5 persons km^2. As such population densities in the African Savannas are, in general, much higher than the northern Australia savanna setting where rural densities are typically as low as <1 person km^2.

Fertile savannas in Africa support very high population densities are economically valued and intensely cultivated or stocked with livestock (see Map 4 and 5). The East and West African Savanna Sub-Regions are relatively fertile savanna regions and have much higher rural population densities, often upwards of 50 persons / km^2 (Little, 2003). In contrast, the Southern African Savanna Sub-Region is largely infertile and population densities rarely exceed 20 persons / km^2 and livestock pressures are no more than 120 animals km^2 (Little, 2003). In areas with higher rural population densities and land use pressure, trends toward privatization and Smallholder Agricultural Livelihoods within infertile savannas are occurring at a rapid pace (Behnke, 2008).



Frequent Late Dry Season Wildfires

Dubbed "The Fire Continent" (Komarek, 1971) Africa experiences more routine burning than any other landmass resulting in the highest fire activity globally (van der Werf *at al.*, 2006, 2008). Like the savannas that sustain them, fire is a complex expression of interconnected drivers. Its effect on ecosystem structure and function, biogeochemical processes, and human development have implications at a range of scales (Bonan, 2008; Beringer *et al.*, 2011).

The arrival of European colonists in many savanna regions attacked TA structures and imposed severe restrictions on burning (Laris, 2002). Since colonial administrations revoked local burning practices and control, savanna fire management has been regulated, with few exceptions, by prevention and suppression oriented fire management legislation and policies (Frost, 1998; FAO, 2006). Typically, insufficient and inconsistent land and fire management legislation, administered by centralized governments with limited capacity, inadequately address the appropriate use of traditional burning to support livelihoods. The absence of clearly defined processes, roles and responsibilities for decision-making, combined with weakening local-level governance and community capacity, results in uncoordinated savanna burning throughout much of Africa. Comparisons between historic and contemporary fires revealed decreases in the number of controlled burns and consequent increases in the size and number of wildfires, but no changes in the purposes for conducting controlled burns or the methods people used to conduct them (Shaffer, 2010). As a result, uncontrolled LDS fires dominate.

Modern GIS technology provides previously elusive information such as ignition frequency and fire size distribution, making it easier to more accurately determine an area's fire regime (Wooster *et al.,* 2003; Giglio, 2007; Archibald *et al.,* 2010). Remotely Sensed data now provides a spatially explicit and comprehensive view of fire in Africa. This makes it easier to progress our understanding of fire regimes (Archibald *et al.,* 2010). However, estimates of frequency, burned area, total pyrogenic emissions, as well as seasonal and inter-annual variation, are still highly uncertain (van der Werf *et al.,* 2006; 2008).

The higher rural population densities and different land use practices within African savannas are important in affecting regional patterns of burning. Savanna burning depends on the availability and arrangement of fuel and largely determined by climate factors. However, human interaction and the associated reduction (cattle density) and fragmentation (roads/cultivation) of fuel loads is important at landscape scale. Increasing human population densities up to around 10 persons / km^2 are associated with more fires, but densities higher than 10 persons / km^2 are associated with fewer fires. SFiM is most feasible in areas with population densities less than 5-10 persons / km^2.

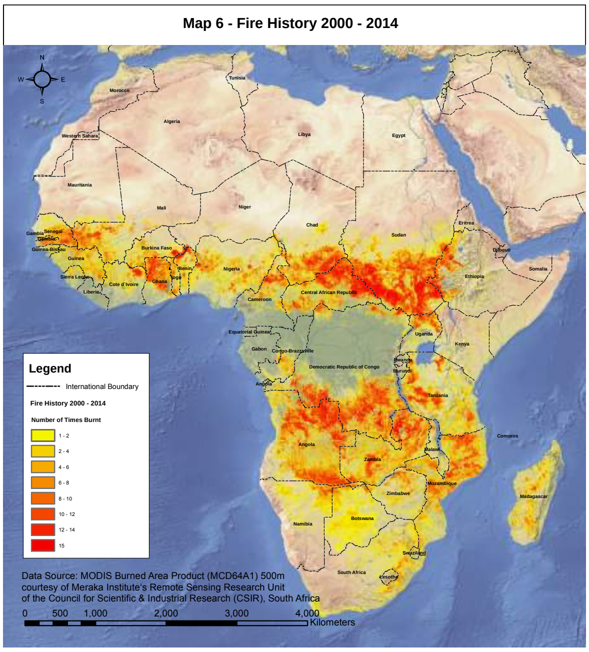
Burned Area

Fuel types in African savannas are generally similar to Australian settings, with fuel consisting of standing grass, shrub leaves, twigs, and fine woody material (Robertson, 2005). Grass fires (not crown fires) generally require a fuel load of at least 1000 kg/ha (McArthur, 1977, Trollope & Potgieter, 1983). Fine fuel, diameter <6 mm (Gambiza *et al.,* 2005) with large surface-area-to-volume ratio, such as tree or grass leaf litter, dries out quickly in response to moisture availability, sustaining the most intense and frequent fire-return intervals on Earth (Archibald *et al.,* 2010).

Savanna fire management depends on the availability and arrangement of fuel and is predominantly determined by climate factors including total rainfall (fuel loads) and seasonality (availability of dry fuels), which are important drivers for fire frequency in savannas (Russell-Smith *et al.,* 2007). Annual precipitation permits abundant grass growth, which dries out quickly during the dry months (Gambiza *et al*., 2005) and becomes available to burn. Where rainfall approaches 800 mm p.a tree cover can exceed 40 % canopy cover. The maximum possible burnt area subsequently declines rapidly, presumably resulting from a reduction in grass fuels as tree density increases (Archibald *et al.,* 2009). This represents a dividing point between stable (rainfall-maintained) and unstable (fire/disturbance-maintained) savannas (Sankaran *et al.,* 2005).

Fire–vegetation–climate relationships found in other savanna systems such as Australia (Spessa *et al.*, 2005) might not easily be transferable to Africa, where much higher rural population densities and different land use practices become important in affecting regional patterns of burning (Frost, 1999; Laris, 2002; Hudak *et al.*, 2004). At a landscape scale, the arrangement of fuel is predominantly determined by human interaction and the associated reduction and fragmentation of fuel loads. Grazing (cattle density) pressure increases alongside population density, increasing with direct consumption / reduction of fuel loads, whereas roads and transformed land (cultivated/urban) fragment fuel loads. In southern Africa burned area is greatly reduced outside PAs that are utilized by humans and their cattle, and further reduced in areas of cultivation and settlement (Archibald *et al.* 2010). Humans can affect fire regimes directly, by altering the ignition regime, and indirectly, by reducing fuels and fragmenting the landscape, thus reducing continuous spread. Subsequently, increasing human interaction both increases the incidence of fire while at the same time decreasing its extent (Archibald *et al.,* 2009). Human effects on fire regimes, then, can be described as the balance between ignition and extinction (Arneth *et al.*, 2010). Increasing human population densities up to around 10 people / km^2 are associated with more fires, but densities higher than 10 people / km^2 are associated with fewer fires (Archibald *et al.,* 2009). In areas of higher population densities within southern Africa most burned area is due to the accumulation of many small- to medium-sized fires from numerous ignitions (Archibald *et al.,* 2010), which can be clearly observed in Zambia.

The average period between fires, or fire frequency, throughout Africa varies greatly, for example, in Western Zambia most areas burn at intervals ranging from once a year to once every 6 to 12 years, depending on the vegetation type and the sources of ignition (Roberston, 2005). Fire frequency is dictated by the climatic and human interaction drivers described above. The results in a similar distribution where it is greatly reduced outside PAs that are utilized by humans and their cattle, and further reduced in areas of cultivation and settlement. PAs and adjacent sparsely populated communal lands typically experience the highest fire frequency with annual-biennial fire return intervals (see Map 6). These areas generally have fewer roads, less cultivation, and a lower biomass of grazing mammals than more populated areas. This accounts for the differences in annual burnt area.



Seasonality

In Africa fires are clearly differentiated as EDS or LDS fires based on fuel characteristics and prevailing weather conditions.

- EDS fires are characterized by low intensity, high degree of patchiness and a tendency to extinguish spontaneously overnight. Light winds, cool temperatures and partially dried fuel (grass, litter etc.) limit the extent of these fires.
- LDS fires are characterized by high intensity, low levels of patchiness and a tendency to spread due to the hot, dry and windy conditions and fully cured fuel. Fires at this time continue to burn, potentially for weeks, until they reach an area of no fuel (river, burnt area etc.) or are manually extinguished.

In the northern hemisphere the fire season (duration of the dry months) lasts from approximately November to March with peak burnt area detected around December (Arneth, *et al.* 2010). In Africa's southern hemisphere, most of the fires take place between March and October, with most fire activity in July, August and September and fires tending to start slightly earlier in countries closer to the Equator (van der Werf, *et al.* 2006; Archibald, *et al.* 2010).

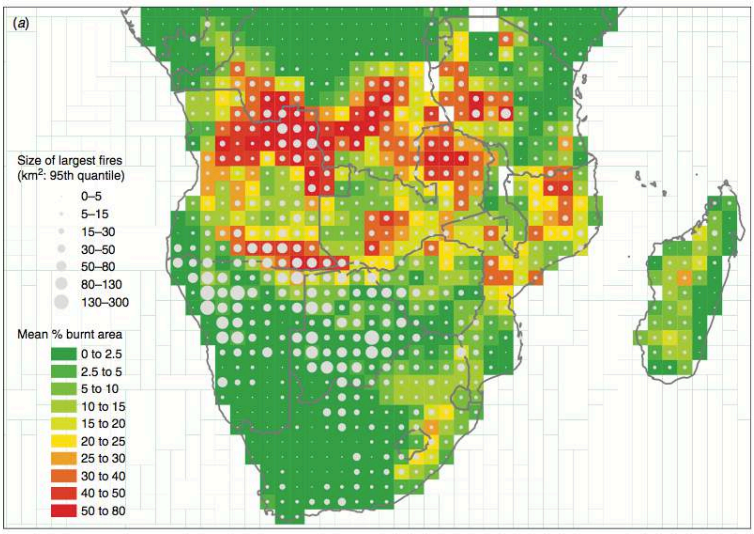
Dry season duration combined with weather conditions (temperature, humidity, and wind) on the day of burning jointly determine fuel moisture (Spessa *et al.*, 2005; Russell-Smith *et al.*, 2007), which is the highest determining factor of fire intensity (Gambiza, *et al.* 2005). Collectively, these combine to influence fire behaviour, characteristics, and expression on the landscape.

In addition to climatic conditions during the LDS that are conducive for fire spread, the source and number of ignitions are also important. Human ignition and use of fire as a land management tool is common throughout the African savanna, where much of the population is rural and land is commonly held (Archibald *et al.,* 2010). People light fires for a plethora of reasons, sometimes accidentally while clearing fields for cultivation, making charcoal, burning rubbish or smoking bees to collect honey. Almost every African Subsistence Livelihood household employs slash-and-burn agricultural practices in the LDS to clear and prepare croplands for ensuing rains with fire often escaping. Other fires are deliberate to produce a green flush of grass regrowth to feed livestock, to clear paths so that people may walk safely, or to attract wildlife for hunting (Chidumayo and Frost, 1996; Sheuyange *et al.,* 2005). These fires represent hundreds of ignition sources distributed throughout the landscape during the hottest and windiest time of the year and lead to extensive uncontrolled wildfires in the LDS.

Wildfires

Similarly, the PAs and adjacent sparsely populated communal lands, with associated fewer roads, less cultivation and lower biomass of grazing mammals also experience the largest fires (see Africa Figure 8). Minimal capacity and resources exist within PAs, or in the surrounding communal lands, to exhibit any form of control over these large fires. As a consequence these uncontrolled wildfires continue to burn until there is a disruption in available fuel, generally when there is nothing left to burn. These fires consume well over half of Africa's total burnt biomass annually (Swap et al., 2003).

Figure 8. Size of Fire



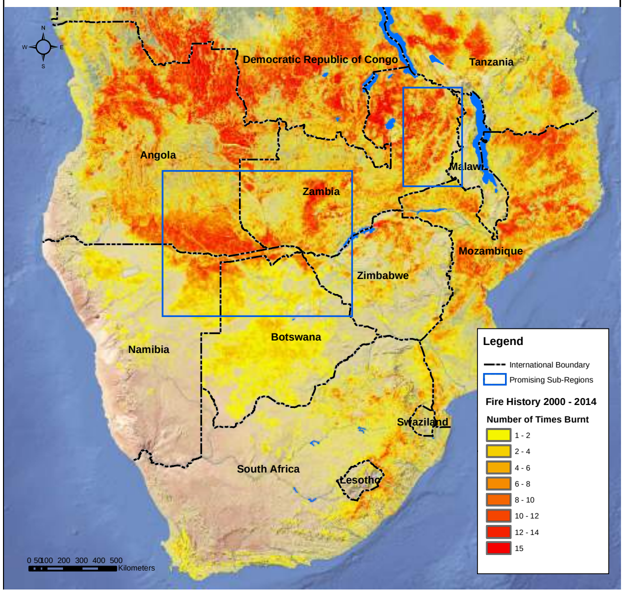
(from Archibald et al., 2010)

Promising Savanna Sub-regions

Based on climate, ecosystem, biodiversity and human interaction characteristics methodology-based SFiM is theoretically possible in certain settings in the three African Savanna Sub-Regions.

The Southern African Savanna Sub-Region is considered more comparable to the northern Australian context and identified as the most feasible for methodology-based SFiM application. Within the Southern African Savanna Sub-Region, which covers approximately 5 million km^2 and comprises 16 countries, two areas have been identified as the most promising.

Map 7 - Promising Sub-Regions



Kavango-Zambezi Sub-Region

The Kavango-Zambezi (KAZA) Sub-Region is situated in the Okavango and Zambezi river basins where the borders of Angola, Botswana, Namibia, Zambia and Zimbabwe converge (See Map 7).

The most well known features are the Okavango Delta (the largest RAMSAR site in the world), Victoria Falls (a World Heritage Site and one of the Natural Wonders of the world), Bwabwata National Park complex in the Caprivi Strip and Chobe National Park.

The Sub-Region's savanna ecosystems, perennial rivers and wetlands combine to provide a diverse array of habitats that support large-scale migrations of mega fauna including the largest contiguous population of African Elephant (approx. 250,000). Other species of global biological importance include threatened species such as African Wild Dog, Wattled Crane, Nile Crocodile and Cheetah. There are more than 3,000 plant species throughout the park, of which 100 are endemic to the sub-region. Over 600 bird species have been identified, as well as 128 reptile species, 50 amphibian species and a diverse range of invertebrate species.

The KAZA Transfrontier Conservation Area (KAZA-TFCA), ranked as the world's largest, spans approximately 520,000 km^2 within the Sub-Region and includes 36 formally proclaimed national parks and a host of game reserves, forest reserves, game management areas, and conservation and tourism concession areas designated for natural resource use. The KAZA Transfrontier Conservation Area (KAZA-TFCA) incorporates a host of protected areas (PAs) and affords a unique position to foster integrated community based natural resource (CBNRM) solutions, with the approximately 2 million inhabitants, across a largely intact landscape.

Frequent (annual-biennial) large-scale uncontrolled wildfires comparable to the northern Australian context are prevalent in the more remote settings in, and around, the PAs of Angola, Namibia and Zambia.

Luangwa Valley Sub-Region

The Luangwa Valley Sub-Region is situated in the Eastern and Muchinga Provinces of northeast Zambia and is centred around the Luangwa Valley (approximately 50,000 km^2) (See Map 7). The Luangwa River is one of the major tributaries of the Zambezi River and one of the largest unaltered river systems in southern Africa supporting Africa's largest population of hippopotamus.

Several large national parks are located within the Luangwa River Valley and include North and South Luangwa, Lukusuzi, and Lower Zambezi National Parks. Numerous Game Management Areas and Forest Reserves exist in close proximity of the Luangwa Valley and represent a much larger interconnect PA network.

The Southern Miombo Woodlands dominates the sub-region and this savanna ecoregion extends through central Zimbabwe, Mozambique, southern Zambia and Malawi. Frequent (annual-biennial) large-scale uncontrolled wildfires comparable to the northern Australian context are prevalent throughout much of the Sub-Region.

The World Bank's BioCarbon Fund (BioCF) has proposed funding a jurisdictional REDD+ pilot programme called the Zambia Integrated Forest Landscape Programme that is focusing on the Luangwa Valley and overlapping regions of the Eastern and Muchinga provinces to reduce GHG emissions from the land sector, whilst simultaneously improving rural livelihoods and wildlife conservation. It aims to operate for 10 years (2015-2024) and will achieve on average emission reductions of 3.5 million tCO2e/year (35 million tCO2e in total). Interest has been expressed in incorporating a SFiM Pilot Project as the fire management component of the Programme.

PART VIII – LATIN AMERICA

There are extensive fire-prone savannas within Latin America. Latin America for the purpose of this Assessment includes all Central and South American countries, including the Caribbean. Among the most significant are the Cerrado of Brazil and Paraguay, the Llanos of Venezuela and Columbia and the Gran Sabana of Venezuela, Brazil and Guyana. Important savannas also exist in Central America, including in Mexico, Honduras, Nicaragua, Belize and the Caribbean.

The different savanna sub-regions of Latin America vary widely in size. In South America the savannas in total cover more than 269 million ha. Most of this, 76%, lies within the Cerrado. The Venezuelan Llanos and the Llanos Orientales of Columbia in contrast cover only 28 million ha. or 11% of the savanna total. These regions are shown in Latin America Fig. 9 '*Regional Overview of Savannas in South America*'. In other parts of the broader region, such as in Central America and the island environments of the Caribbean, tracts of savanna may be much smaller, such as such as in the case of Belize where the Pine Savannas are less than 3,000 km2. Notwithstanding their small size, some of these smaller savanna areas have great importance in terms of their unique ecosystems and biodiversity.

Figure. 9 Regional Overview of Savannas in South America

Considered in this assessment are three sub-regions of South America: the Llanos of Venezuela and Columbia, the Cerrado of Brazil, Bolivia and Paraguay; and Gran Sabana of Venezuela and Guyana. Also considered, and representing Central America, are the savannas of Belize. These regions were selected for particular attention based upon size of the savanna, fire occurrence, biological diversity, presence of indigenous fire use, and other indications of potential capacity to implement methodology-based savanna fire management, as suggested by the pre-conditions identified in Part V of this report.

Literature searches, satellite imagery and interviews with subject-matter-experts were used to assemble this assessment. The assessment characterises fire occurrence, seasonality of fire as well as landscape ecology of those sub-regions containing the largest and most biologically diverse savannas, and provides emissions data where possible.

In the course of developing this assessment clear patterns emerged, namely:

- South American savannas face significant threats. With the on-going expansion of agriculture, they are under going rapid conversion. Of the South American savannas, 71% have been converted to croplands and 5% are now urban areas (White *et al.,* 2001). Intense, destructive wildfires in savanna are a significant problem in the region, coming at great economic cost and damaging infrastructure and biodiversity.

- There is a growing recognition in all savanna sub-regions of Latin America that severe dry season wildfires are having negative impacts upon public health and safety due to the direct impacts of particulate emissions and regional haze during peak burning seasons.

- Fire-induced crop loss and impacts upon local and regional livelihoods are increasingly untenable as populations increase and fires become more frequent. Tourism and visitor enjoyment is being impacted by smoke events, thus affecting income.

- In all savannas analysed, fires are impacting biodiversity due to severe impacts on fire-sensitive forests adjacent or embedded in fire-prone savannas. Beyond biodiversity concerns, destruction of forested areas decreases the carbon sequestration capacity of standing forests.

- Policy and legislation in the sub-regions considered frequently focuses on prohibition and suppression, despite the scientific evidence demonstrating the benefits of a more integrated fire management based approach. Some programmes are in place to explore and demonstrate the benefits of a fire management as an alternate approach.

- Indigenous peoples in all sub-regions have long histories of fire management, using fire for a range of cultural, livelihoods and ecological management purposes. There is also increasing interest in the role of indigenous people and their traditional knowledge of fire use throughout the region. Governments are beginning to recognize the benefits of partnerships with tribes to work together to solve problems associated with severe, large-scale wild land fire events.

- The savannas of the region demonstrate both similarities and differences to Australian conditions, and in reference to other savannas of the region. Each sub-region thus requires separate analysis and consideration when assessing the potential for SFiM that draws from the Australian experience.
- In all of the above savannas and perhaps others in the region (i.e. Mexican savannas and the Miskito savanna of Honduras and Nicaragua), the application of methodology-based SFiM is likely to be theoretically possible upon the development of locally appropriate methodologies.
- While a great deal more work is required across the scientific, technical, demand side, and legal and policy domains, much of the basic capacity to operationalise the potential of SFiM including through development and application of methodology-based approaches, exists in regions assessed in this assessment
- To further explore this potential in specific areas, and to identify the steps required and resourcing needs, priority site pre-feasibility assessments, available separately, were developed for each of:
    - the Gran Sabana within Venezuela in the region of Canaima National Park.
    - the Terras Indigenas of the Cerrado of the Tocantins state of Brazil.
    - the Southern Belize Pine Savannas..

The following sub-regional analysis focuses in turn on the Llanos of Colombia and Venezuela, the Cerrado of Brazil, Bolivia and Paraguay, the Gran Sabana of Venezuela, Guyana and Brazil.

Llanos of Colombia and Venezuela

The Llanos of Colombia and Venezuela is an ecosystem of flammable savanna vegetation. These are ecosystems of economic importance for both countries. The World Wildlife Fund (WWF) has evaluated the status of this area as "vulnerable". Because of the presence of highly flammable C3 & C4 grasses and abundant human-caused ignition sources, the Llanos support extensive fires.

Ecosystem and Biodiversity Characteristics

Originating below the slopes near Oriental Andes of Colombia and following the valley landforms of the Orinoco River to where they meet wet flood plain vegetation and mangrove forests at the sea, the Llanos ecoregion extends over an area 1200-1300 km. The Llanos ecoregion is located in a great depression, limited by the Andes in the west, the Venezuelan coastal range that isolates it from the Caribbean Sea in the north, and the Guiana shield in the south. In Venezuela this eco-region is within the states of Apure, Barinas, Cojedes, Portuguesa, Guarico, Anzoategui and Monagas. In Colombia the savannas are within the departments of Meta, Arauca, Vichada and Casanare. These savannas are within a matrix of topography, hydrology and local weather patterns creating a high level of heterogeneity in the landscape and vegetation types. Fed by the Andes and Guiana plateau, several rivers flow through the landscape to meet the Orinoco River.

Due to the complexity of the landscape, several investigators have attempted to classify this interlocking puzzle into as many as seven areas (Huber and Alarcón, 1988; Blydenstein, 1962,1967; Etter, 1998; Rangel *et al.,* 1995; Rippstein *et al.,* 2001). These classifications are based upon vegetation topography, substrate and hydrological response. Hydro-periods of flooding and drying directly relate to flammability and available fuels. Like many seasonally hydrated savannas, when the landscape is dry greater connectivity of available fuels exists. This increases the probability of ignition and large-scale, severe fires.

Vegetation

Subtle changes in topography, hydrology and soil characteristics, along with the presence of trees and shrubs, contribute to a high level of floral heterogeneity. Approximately 65% of the Venezuelan savannas, totalling 28 million ha, are characterised by the grass species *Trachypogon* (San José and Montes, 1989). A total of 285 species of angiosperms belonging to 55 families have been reported for these savannas (San José and Montes, 1989). These are non-flooded savannas that grow mainly on the "llanos altos" or high plains, over poor soils with very low nutrient content, many times with a lateritic hardpan layer near or at the surface of the soil. These soils are often ultisol and oxisols overlaid with accumulated organic matter in low areas. In a typical Trachypogon spp. savanna, characteristic species are:

- *Trachypogon plumosus, T. vestitus, Axonopus canescens, A. anceps, Andropogon selloanus*, several species of the genus *Aristida*, *Leptocoryphium lanatum, Paspalum carinatum, Sporobolus indicus, S. cubensis*, sedges of the genera *Rhynchospora* and *Bulbostylis*.

- Legumes of the genera *Mimosa, Cassia, Desmodium, Eriosema, Galactia, Indigofera, Phaseolus, Stylosanthes, Tephrosia*, and *Zornia*.
- Scattered trees belonging mostly to two species, the "manteco" (*Byrsonima crassifolia*) and the "chaparro" (*Curatella americana*) occur rather frequently, as does the "alcornoque" (*Bodwichia virgilioides*).

Groups of trees, usually called "matas", are common, with sizes that vary between less than 12 m in diameter to one ha or more. They are considered remnants of the deciduous dry forest that covered much larger areas some years ago. Human populations are rapidly destroying these through the use of fire and other land conversion practices. These savannas have been used traditionally for extensive cattle raising despite their grasses being of poor quality and their productivity low. Within the region, vegetation classification and habitat identification remains challenging. Scientists working in Colombia and Venezuela have not yet having homogenized the nomenclature, making the comparison between both countries difficult.

Two seasonally flooded savanna types that are embedded in the drier sites support some level of inundation for a few to several months a year. They are the *Paspalum fasciculatum* savannas and the savannas of "banco, bajio and estero". The *Paspalum fasciculatum* savannas, locally called "gamelotales", are almost monospecific communities, that support over two meters of water at peak rainfall, grow over much better soils than the Trachypogon savannas, have high productivity (up to 25 tn/ha) and provide good pastures during the drought (Escobar, 1977). They comprise about 15% of all Venezuelan savannas. The second important type of flooded savanna is the "banco, bajio, and estero" savanna that, in Venezuela, represents about 20% of the Llanos. These savannas are named for the topography of the place where they grow, upon slopes with scarcely two meters level difference between its upper and lower parts. The "banco" is the higher area, originally the bank of a former river that has a changed course. The bancos are elongated areas, with sandy soils and many of them include remnants of their former gallery forest vegetation. They have a rich flora dominated by grasses (Gonzalez and Escobar, 1977; Bulla *et al.,* 1990), occupy 60-80% of these savannas and are flooded with 5-20 cm of water at peak rainfall. They have a mixture of C3 and C4 grasses. Finally the "esteros" occupy the lower part of these savannas, where water accumulates during the rainy season reaching 50-80 cm depth. The esteros are covered by C3 hydrophilus grasses.

An important vegetation feature of Llanos are gallery forests (Huber and Alarcón, 1988; Etter, 1998). These gallery forests are biologically diverse, but contain fire sensitive species. Dry-season fires induce direct mortality in these ecosystems and degrade biodiversity and ecosystem function. Gallery forests are refugia for species that avoid direct impacts form fire and serve as important sites for carbon sequestration. When present along riparian zones, these forests filter upland run off into streams. The most important of these are:

1. Gallery forests of various types that follow the courses of the streams and rivers. In some cases the rivers overflow their banks limiting the gallery forest so it coincides with the extent of the flooding, behaving as a seasonal swamp forest. A special case is the "morichales" characterized by the presence of the palm *Mauritia flexuosa*, and the Orinoco "vegas", evergreen forests of 8 to 20 m high whose more common species are *Inga spp., Combretum frangulifolium, Gustavia augusta, Pterocarpus sp., Etaballia dubia, Spondias mombin, Copaifera pubiflora,* etc. In other cases the forest occurs on the higher banks where they avoid flooding and most trees are semi deciduous, of medium height (12-15 m), with a well-developed understory.
2. Deciduous dry forests probably covered most of the northern part of the central high Venezuelan Llanos, but have been reduced to isolated patches or even very small "matas" due to increased anthropogenic dry-season fires emanating from agriculture and land clearing. These are deciduous woods 8-15 m high, very dense, with well-developed understories of semi-deciduous shrub stratum. Although their floristic composition varies, frequent species include *Tabebuia billbergii, Godmania aesculifolia, Cassia moschata, Spondias mombin, Copaifera pubiflora, Bourreria cumanensis,* several species of *Cordia, Bursera simaruba, Cochlospermum vitifolium, Hura crepitans,* and *Acacia glomerosa* (Huber and Alarcón, 1988).

For the Colombian Llanos, Rangel *et al.,* (1995) reported 2,126 species of plants belonging to 807 genera and 180 families. The highest diversity corresponds to the Rubiaceae family with over seven hundred species, and the Leguminosae (255), Poaceae (214) and Cyperaceae (96). Geographically, the highest diversity is found in the high plains area of the ecoregion with over 1,500 species.

Biodiversity

The Llanos ecoregion has less biotic diversity and fewer endemic species than the adjacent ecoregions – while most biodiversity is found in the forests (Ojasti, 1990; Rangel *et al.,* 1995; Stotz e*t al.,* 1996; Péfaur y Rivero, 2000). There are a small number of endemic plant species in the Llanos. For the savannas, Huber & Alarcon (1988) list *Vernonia aristeguietae, Bourreria aristeguietana, Stilpnopappus pittieri, S. apurensis, Hymenocallis venezuelensis, Eriocaulon rubescens, Limnosipanea ternifolia;* and in the gallery forests, *Gustavia acuta.* The open savannas are the least used habitat by the megafauna of this ecoregion, and most of the faunistic richness is concentrated around permanent and temporary water sources (Pérez and Ojasti, 1996).

According to Ojasti (1990), there are 102 species of mammals in the Venezuelan Llanos; about 31% of the terrestrial mammal fauna of Venezuela (Linares, 1998). Most of them are Chiroptera with 59 species, however there are also Rodentia (17 species), Carnivora (11 species), Edentada (5 species), Marsupialia (4 species), Primates (2 species), Artiodactyla (2 species), Perissodactyla (1 species) and Lagomorpha (1 species). The mammalian fauna of neo-tropical savannas is rather poor, considering their geographical extent. A surprising characteristic of the Llanos fauna is the almost complete absence of native ungulates, especially in comparison with the African savannas. Almost all African ungulates are specialised for the savanna ecosystem, whereas in the Orinoquia savannas only the white-tailed deer (*Odocoileus virginianus*) is found, and even this species reaches its highest densities in the gallery forest and the savanna-forest ecotone (Eisenberg, 1999). In the wet and flooded savannas, the large herbivore ecological niche is occupied by the largest existing rodent, the capybara (*Hydrochoerus hydrochaeris*), which reaches weights over 50 kg (Ojasti, 1993). Besides this species, the mammals more commonly found in the open savannas are the savanna rabbit (*Sylvilagus floridanus*), and several species of rodents including *Sigmodon alstoni, S. hispidus, Zygondotomys brevicauda*, and *Orizomys bicolor* (Ojasti, 1990). In the gallery forest there is a much greater diversity of large and medium-size mammals including pecaríes (*Tayassu tajacu* and *T. pecari*), tapirs (*Tapirus terrestris*), deer (*Odocoileus virginianus, Mazama americana*), monkeys (*Cebus nigrivittatus, Alouatta seniculus*), large rodents (*Agouti paca, Dasyprocta spp, Coendou prehensilis*), and several felides like pumas (*Puma concolor*), jaguars (*Panthera onca*), and ocelots (*Leopardus pardalis*).

Colombia has the richest avifauna of any country in the world (more than 1700 bird species), but less than 40% of them are found in the Colombian Llanos (Rangel *et al.,* 1995). Roughly, at least half of the 1,313 bird species recorded in Venezuela (Phelps and Meyer, 1978) include the Llanos in their distribution. More than one hundred of the birds reported for the Orinoquia are migratory birds that winter in the Llanos (Stotz *et al.,* 1996). Most of the birds of the Llanos inhabit and are usually restricted to the gallery forest (Stotz *et al.,* 1996). In contrast, habitat specialisation is rare in savanna birds, and many of them are able to proliferate in agricultural areas, as is the case for almost all seed eating birds (pigeons, doves, finches, sparrows, crested bobwhite). Wading and aquatic birds represent a large portion of the total bird fauna in the flooded savannas (Pinowsky and Morales, 1981; Gomez-Dallmeier and Cringan 1989), and are one of the major tourist attractions in the ecoregion given that many of them are large colourful birds that form large aggregations around water sources.

Fairly large numbers of herpetological fauna exist in this ecoregion; mainly in the forests and the "bancos, bajíos, and esteros" savannas, although the numbers are comparatively poor in

Trachypogon savannas (Rivero-Blanco and Dixon, 1979). A total of 36 amphibians and 75 reptiles have been reported for the Venezuelan Llanos (Péfaur and Rivero, 2000), whereas 28 amphibians and 119 reptiles are included in the list of species for the Colombian llanos (Rangel *et al.,* 1995). Some reptile species deserve mention: Arrau sideneck or Orinoco turtle (*Podocnemis expansa*), the largest american fluvial turtle, reaching weights of over 50 kg; the Orinoco crocodile (*Crocodylus intermedius*) which is the only species of crocodile restricted to a single river basin, and the red-footed tortoise (*Geochelone carbonaria*) which is the wild species more frequently used as food for rural populations in the area (Ojasti, 1993).

There are no endemic birds restricted to the Llanos ecoregion (Wege and Long 1995), and only two mammals: the marsupial *Monodelphis orinoci* and the edentate *Dasypus sabanicola* (Eisenberg and Polisar, 1999). Herpetological endemism in the Llanos is very low in comparison with adjacent ecoregions (Péfaur and Rivero, 2000). One of them is the Orinoco crocodile (*Crocodylus intermedius*), one of the most world's endangered crocodilians (Muñoz and Thorbjarnarson, 2000).

Several species are identified as being at risk of extinction; the giant armadillo (*Priodontes maximus*) virtually extinct north of the Orinoco; the giant river otter (*Pteronura brasiliensis*), one of the most endangered otter species of Latin America; the ocelot (*Leopardus pardalis*) that although severely affected in the Llanos persists in the forests south of the Orinoco river; the jaguar (*Pantera onca*), the largest american felidae which has been severely hunted in the llanos both for sport and alleged cattle attacks; the tapir (*Tapirus terrestris*), now drastically reduced to some scattered areas; the manati (*Trichechus manatus*), still abundant in some areas of the high Orinoco though intensively hunted; the Arrau sideneck (*Podocnemis expansa*); and finally, the Orinoco crocodile (*Crocodylus intermedius*). Bird species of the area listed as vulnerable are: the sharp-tailed ibis (*Cerbibis oxycerca*) whose distribution is restricted to the llanos and is the most scarce ibis species found in Colombia and Venezuela; and the scarlet macaw (*Ara macao*), the macaw most used as a pet (Rodriguez and Rojas-Suarez, 1999 and the appendix III of CITES for Colombia).

Threats

In terms of agriculture and associated fire use, cattle raising is by far the main activity in the ecoregion and it is responsible for many changes in the area. There are 15 million head of cattle in the ecoregion (MAC 1998; Pardo *et al.,* 1999). Given the low quality of the native grasses, fire is used regularly to increase their quality, the forests are cleared to increase pasture land and natural savannas are being replaced by introduced pastures. There are 1.3 million ha. being used as introduced pastures in the Colombian Llanos (Pardo *et al.,* 1998), and about 4 million in its Venezuelan counterpart (MAC 1998). In addition, a rapidly increasing area is being cultivated with different crops, especially corn and rice. The 200,000 ha. dedicated to the rice crops in the western Venezuelan llanos attracts huge flocks of migrant birds such as whistling ducks (*Dendrocygna viduata, D. autumnalis*, and *D. bicolor*) and the dickcissel (*Spiza americana*). These birds cause serious damage to the crops that in some cases may reach 100% of the harvest (Gómez-Dallmeier and Cringan, 1989). Because of this, ranch owners kill these birds in large numbers. Dickcissel is now considered an endangered species (Stotz *et al.,* 1996) due to the rapid decrease in ipopulation numbers, caused in part by this massive annihilation in the rice crops of Venezuela (Audubon, Dickcissel research project).

In terms of deforestation and farming for the wood industry, the Venezuelan Llanos have the highest deforestation rate in the country (Bisbal, 1988). Between 1950 and 1975, 1.3 million ha. were deforested in the western Venezuelan Lanos (Veillon, 1977) - from this date to present the average deforestation rate in all Venezuelan Llanos has been 34,000 ha/year (Bisbal, 1988). A similar situation occurs in the foothills of the Colombian Orinoquia where deforestation reached figures of 4.4% between 1979 and 1988 (Viña and Cavelier, 1999). In contrast, half a million ha. of savannas in the llanos of Monagas have been transformed to *Pinus caribeae* plantations during the last 30 years, and about 100,000 ha more is expected to be sowed at Guarico State in coming years. The pines completely eliminate the original savanna vegetation, a fact that greatly affects the fauna of the area (Bulla and Bach, 1999). In places where the pines have been harvested, there is some indication that a comparatively fast recovery of the savanna takes place, however a minimum of 20 years seems necessary to achieve near natural condition.

In terms of industrial activities, almost 3 million ha of Venezuelan llanos has been affected by the oil industry (Bisbal, 1988). This is also one of the main threats in the Colombian Orinoquia. This is because it may produce a wide range of disturbances, such as deforestation, habitat fragmentation through the construction of roads, incroachment of human settlements, as well as air and water contamination (Rangel *et al.,* 1995). Both roads and settlements increase the human use of fire and uncontrolled wildfire.

The Llanos ecoregion is also the most affected by the construction of dikes in Venezuela (Bisbal, 1988). All over the ecoregion there are thousands of small permanent ponds made by landowners to provide water to their livestock during the drought, which also benefits wildlife. In the "banco, bajío, and estero" savannas, an area of 190.000 ha. has been covered by a network of low dikes, the so-called "Modulos de Apure", whose purpose is to control flooding during the rainy season and save water for the cattle during the drought. This transformation completely alters the hydrologic flood/drought cycle of these savannas, artificially increasing the level of flooding and almost eliminating drought. Drying organic soils become consumed by wildfire. These changes greatly impact the vegetation, reducing its diversity by half (Bulla *et al.,* 1990), but benefit livestock (Tejos *et al.,* 1990), as well as aquatic and wetland fauna (Ramos *et al.,* 1981; Pinowski and Morales, 1981).

Invasive Non-native Species

Flammable non-native grasses are quickly invading the savannas. These include African grasses that behaving as very aggressive invaders in Lllano savannas and increasing fire intensity (Baruch, 1996). These are *Melinis minutiflora*, very successful in savannas above 600 metres above sea leve and rather abundant in Colombia; *Hyparrenia rufa*, in lowland savannas with poor soils and marked dry season; *Panicum maximum*, in humid and relatively fertile areas, and *Brachiaria mutica* in periodically flooded savannas. All these species generally occur on the wetter (but not inundable) and/or more fertile habitats of the savanna, and are consequently favoured by the fertilisers used in agriculture.

Indigenous Cultures and Relationship with Fire Use

Several indigenous groups live in rural communities within the Venezuelan Llanos. The largest group is the Kariña, with an estimated population of 7,253, followed by the Pumé (or Yaruro) with 5,321, the Warao with 2,485, the Guahibo with 333, the Kuiva (or Cuiba) with 325 and the Wayuu with only two individuals left. The Pumé, Guahibo, and Kuiva occupy the south western areas around the Capanaparo and Cinaruco Rivers, and support themselves mostly by fishing, hunting, and traditional agriculture, with yucca being one of the principal crops. Some of the younger Pumés speak Spanish and occasionally travel to populated areas to work as crop hands or in other seasonal jobs. Mostly, however, these groups still live a traditional subsistence life-style using fire as a management tool. The Kariña and Warao occupy the Eastern high plains, the latter being the predominant ethnic group of the Orinoco Delta.

In Colombia, there are 11 indigenous groups in the Llanos, with the vast majority of comprising the Sikuani. Others include the Cuia, Saliba, Tenubo, Macaguane, Guahibo, Piapoco, Guayabero, Curripaco, Betoye, and Piaroa peoples. The total population is 23,556, with the indigenous populations inhabiting a series of Indigenous Reserves (Resguardos Indígenas), covering 2,818,182 ha. (Romero *et al.,* 1993). These cultures have a long history of fire use that may conflict with government policies.

Current Status

Ecological change in the Llanos savanna has been significant (Bisbal, 1988; Rippstein *et al.,* 2000), and will continue to increase in the future. This is because this ecoregion is the centre of agricultural production, and more recently, of oil production for both countries.

Protected in the Colombian Orinoquia as national parks of "Cordillera de Los Picachos", "El Tuparro" and "Tinigua" are 1.2 million h. of Llanos (Rangel *et al.,* 1995). In the Venezuelan Llanos1.2 million ha. are protected in the national parks of "Aguaro-Guariquito" in the high llanos, "Cinaruco-Caparo" in the lowlands of Apure State, and "Río Viejo". In addition, there are four fauna refugia: "Tortuga Arrau", "Caño Guaritico", "Estero de Chiriguare" and "Morichal Largo''.

Cerrado: Brazil, into Bolivia and Paraguay

Ecosystem and Biodiversity Characteristics

The Cerrado is the largest savanna region in South America and biologically the richest savanna in the world. Located throughout Brazil Paraguay and Bolivia, the Cerrado is home to over 10,400 species of vascular plants, fifty of these endemic. Fauna diversity is very high also with 180 species of reptiles, 113 of amphibians, 837 of birds and 195 of mammals. Major efforts are needed to preserve what is one of the biologically richest savannas in the world, since only one percent of this ecoregion is protected and agricultural development continues to destroy habitat. The Cerrado is also one of the most active sites for wildland fire in the western hemisphere.

The Cerrado encompasses Central Brazil (most of Mato Grosso, Mato Grosso do Sul, and Tocantins; western Minas Gerais and Bahia; southern Maranhão and Piauí; all Goiás and Distrito Federal; and small portions of São Paulo and Paraná), northeastern Paraguay and eastern Bolivia (Ab'Saber, 1983). Because of its central position in South America, the Cerrado has borders with the largest South American biomes: the Amazon basin (on north), Chaco and Pantanal (on west), Caatinga (on northeast), and Atlantic forest (on east and south). Several of the major South American rivers, for example the São Francisco, Tocantins, Araguaia, Xingu, and Paraguay, have their headwaters in Cerrado (Ab'Saber, 1983). Most of the Cerrado is located on large blocks of crystalline or sedimentary plateaus, whose continuity is broken by an extensive network of peripheral depressions (Brasil & Alvarenga, 1989). On plateaus ranging in elevation from 500 to 1,700 m, the landscape is dominated by cerrado vegetation, with narrow fringes of gallery forests along the rivers and streams (Eiten, 1990). On the depressions, ranging in elevation from 100 to 500 m, different types of vegetation (broad gallery forest, tropical dry forests, all types of cerrado, and marshlands) are distributed in a mosaic fashion (Silva, 1995). The cerrado vegetation covers around 95 percent of the ecoregion (Eiten, 1990). It is a savanna like vegetation that grows on nutrient-poor, often deep and well-drained soils (Furley & Ratter, 1988). Throughout its range, cerrado vegetation varies much in physiognomy and composition, from an open field ("campo limpo") to a tall closed forest ("cerradão") (Ribeiro *et al.,* 1983). The climate is seasonally tropical. The dry period, from May through September or

October, coincides with the coldest months of the year (Nimer, 1979). The average annual rainfall varies between 1,250 and 2,000 mm, and the average annual temperature ranges from 20° to 26° C (Nimer, 1979). Cerrado harbours a very distinctive biota, with thousands of endemic species. Every single biogeography analysis in South America has pointed to the Cerrado as an important and distinctive area of endemism for different groups of organisms (Silva, 1995).

Biodiversity Features

The Cerrado is rich in biodiversity, with at least 10,400 species of vascular plants, 780 fish species, 180 reptile species, 113 amphibian species, 837 bird species and 195 mammal species (Cavalcanti, 1999). Most of these species are restricted to cerrado. The percentage of endemic species varies among taxonomic groups, with 4% endemism among birds to 50% endemism in vascular plants. Cerrado is also a unique evolutionary theatre where species from the largest South American forests (Amazon and Atlantic Forest) and from the largest South American dry habitats (Chaco and Caatinga) intertwine (Silva, 1995).

Distinctive species include the plants: *Caryocar brasiliense, Qualea grandiflora, Byrsonima coccolobifolia,* and *Tabebuia ochracea*; birds including the lesser nothura (*Nothura minor*), dwarf tinamou (*Taoniscus nanus*), blue-eyed ground-dove (*Columbina cyanopis*), white-winged nightjar (*Caprimulgus candicans*), Brasília tapaculo (*Scytalopus novacapitalis*), and cinereous warbling-finch (*Poospiza cinerea*); mammals including the candango mouse (*Juscelinomys candango*), cerrado mouse (*Thalpomys cerradensis*), Lindbergh's grass mouse (*Akodon lindberghi*), pygmy short-tailed opossum *Monodelphis kunsi*), giant armadillo (*Priodontes naximus*), and the maned wolf (*Chrysoicyon brachyurus*); and lizards including *Tropidurus itambere, Tropidurus oreadicus*, and *Tupinambis duseni*.

Current Status

Around 67% of the cerrado ecoregion has been significantly altered by human activities (Mantovani & Pereira, 1998). Parks or reserves protect only one percent of the total area of the Cerrado. The establishment and construction of the new capital of Brazil (Brasília), the construction of several highways alongside several investment Programmes financed by multilateral funding agencies together with generous government subsidies have transformed the cerrado in a new agricultural frontier. Managed pastures and large-scale plantations of soybeans, corn, and irrigated rice have been established on a significant scale.

Threats

In addition to the threats to cerrado biodiversity due to large scale agricultural projects, cerrado areas continue to be degraded as a result of on-going encroachment of human populations. In Piauí, Tocantins and Maranhão states, fire use on the frontiers due to agricultural burning and other incendiary sources is increasing the frequency, timing and magnitude of impacts. Severe burn scars serve as vectors for many of the African invasive grasses to enter natural areas (Rossi *et al.,* 2014).

Indigenous Fire Management Practices

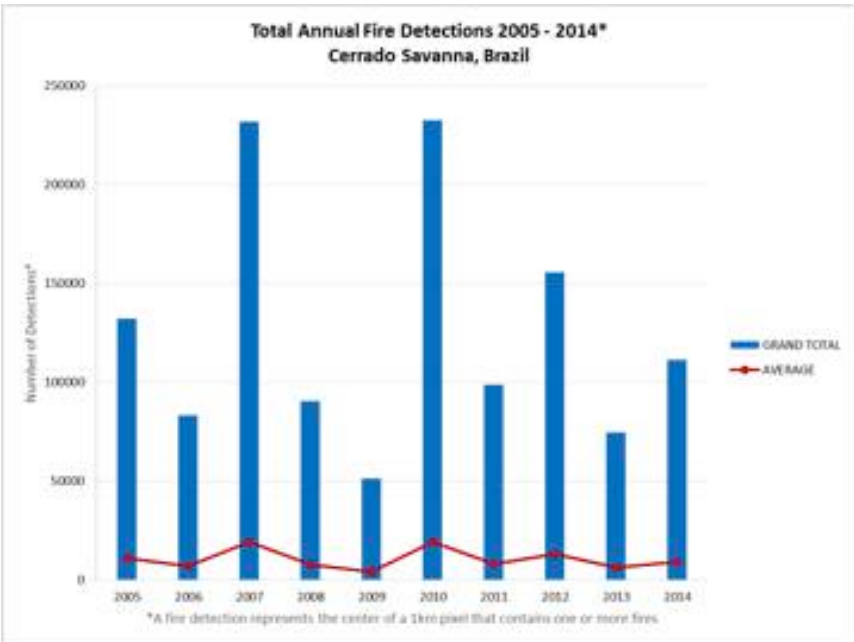
Semi-nomadic peoples were actively using fire in the cerrado and in the rain forest borders by 4000 to 5000 years B.C. (Fiedel, 1992). This management practice was passed to their descendants and, consequently, the use of fire was very widespread among most indigenous groups in Brazil, especially those belonging to the linguistic families Jê (e.g., Xavante, Krahô, Kayapó) (Maybury-Lewis, 1984; Anderson and Posey, 1985; Mistry *et al.,* 2005; Melo, 2007), Aruák (Silva, 2009), and Tupi-Guarani (e.g., Guarani, Ka'apor, Guajá, Tembé) (Godoy, 1963; Balée, 1993).

Some groups who lived and still live in the forest-savanna borders, and who are better known to scientists, such as Kayapó, Tupi-Gua- rani, Krahô, and Bororo, practiced very refined fire management methods. The Kayapó, for example, recognized and managed more than 40 types of forests, savannas, and grasslands. They used fire to create islands of resources (orchard patches) where they planted several species of fruit trees and other useful plants. Fire was used to make firebreaks around these orchards to protect them from accidental burns. Specific fire regimes were applied to stimulate the flowering and fruiting of some species or to control plant diseases.

Cool burns during the first spring rains were also carried out to fertilize the soil through the ashes deposited on soil surface, without damaging the plants. Therefore, mosaic patch-burns in savannas were used to increase the diversity of useful plants and resources (Anderson and Posey, 1985).

Figure 10. Fire detections in the Cerrado

Figure 11. Fire detections in the Cerrado



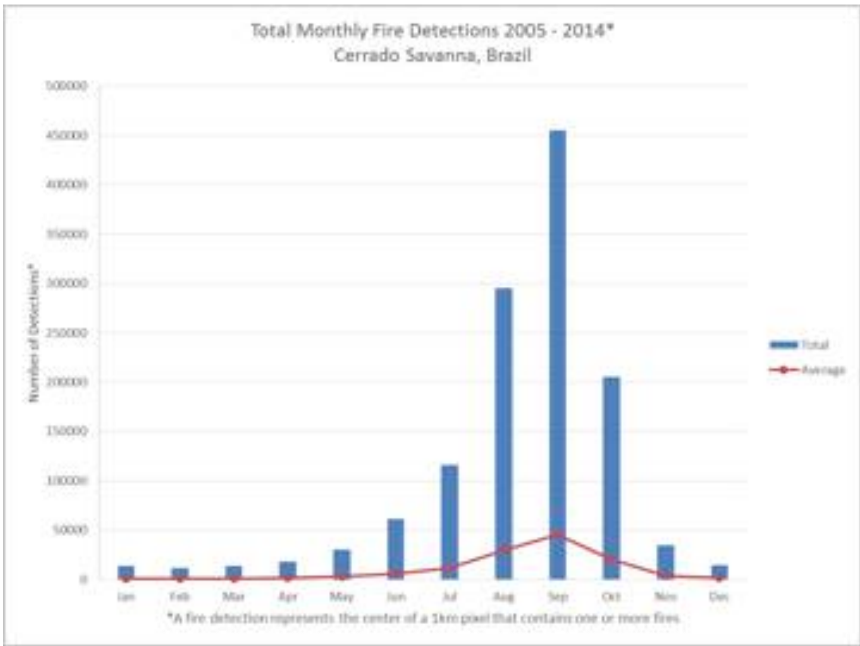


Figure 12. Fire seasonality in the Cerrado

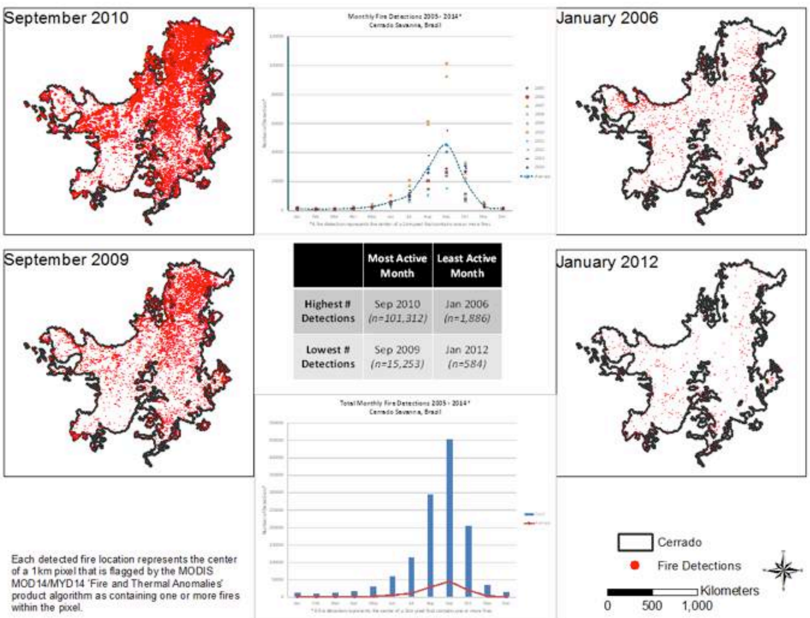
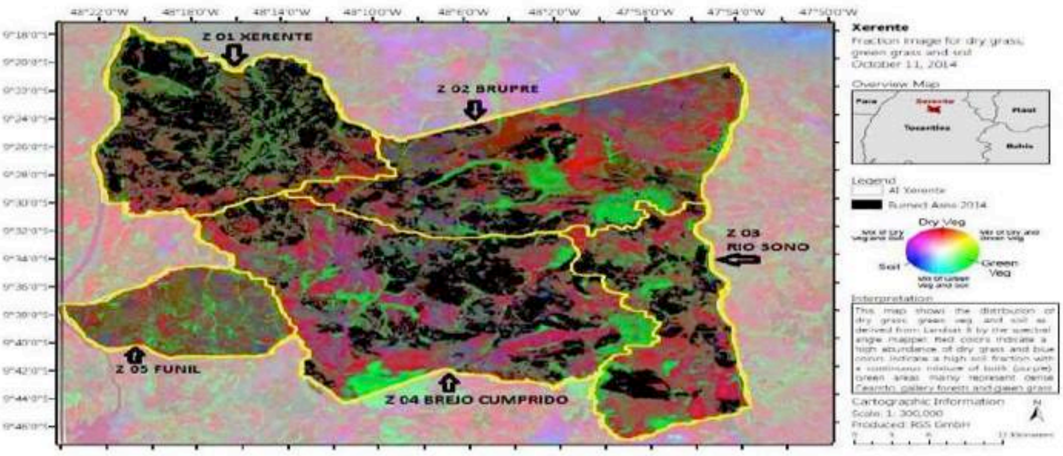


Figure 13. Example of Indigenous Xerente Patch-Burn Mosaics



As a flammable savanna ecosystem with anthropogenic fires, Brazil is in the process of developing and implementing strategies such as Integrated Fire Management Myers, 2000) to abate the risks of large-scale severe wildfires in the region. With rapidly increasing commercial development and associated land clearing, approximately half the original vegetation cover remains intact. Each year, uncontrolled wildfires spread throughout the region, with serious consequences including loss of biodiversity, increased GHG emissions, and negative impacts on land use and community livelihoods.

Between 2003 and 2005, the Cerrado accounted for ~25% of Brazil's land-use-related CO2 emissions, predominantly through deforestation and wildfires. Brazil's National Action Plan on Climate Change and Action Plan for Prevention and Control of Deforestation and Wildfires in the Cerrado has targeted a 40% reduction in these emissions by 2020.

Improved prevention and control of wildfires and new fire and land clearance monitoring systems are required to protect the Cerrado as a globally significant carbon reservoir and preserve its biodiversity – as envisioned by the Brazilian-German Cooperation Project "Prevention, Control and Monitoring of Bushfires in the Cerrado". Uncontrolled wildfires are negatively impacting upon major land uses including industrialized large-scale commercial agriculture, livestock production and silviculture; smallholder agro-pastoralism; protected area management and tourism; and the sustainability of indigenous and other community livelihoods. These cross-sectoral issues highlight the importance of socio-economic factors in the management of fire and the necessity to engage public, private and civil society stakeholders. To address these issues the Brazilian-German Cooperation Project has been investigating Integrated Fire Management (IFM) strategies to achieve land use objectives, reduce greenhouse gas (GHG) emissions and enhance community livelihoods through productive and sustainable land use practices in the Cerrado. At least one workshop and other activities have been conducted with Xavante and Funil tribes by

Prevfogo, the Brazilian government agency entity with Fire Management responsibilities for the "Terra Indigenous" (Beatty, 2015) (Anja Hoffman GIZ personal communication, 2015).

Gran Sabana Venezuela, Guyana and Brazil

The Gran Sabana occurs in three large patches across northern Brazil and extending into Guyana, Suriname, and Venezuela. "Islands" of small savanna patches also occur along the north western parts of the ecoregion. In the Gran Sabana, and typical of other savannas in the western hemisphere, recurrent fires and extremely poor soils are a driving factor in savannas in resisting the establishment of over story species. While an important number of endemics are found in the Gran Sabana, overall endemism is low.

As in many savannas of Central and South America, fire-sensitive moist forests are embedded within the landscape and are isolated from each other and other similar habitats – and contain a number of endemic species. This ecoregion occupies an area within the Roraima geological formation distinguished by extensive savannas and scrub vegetation. The region is traversed by streams and, similar to Llanos and Cerrado, gallery forests and extensive savanna tracts.

Location and General Description

The savanna encompasses the treeless and tree patch mosaic of the Gran Sabana, and occurs as three distinct outliers: the largest spanning northern Brazil, south-eastern Venezuela, and south-eastern Guyana (also several small patches extending north along the Pakarima footfills); a smaller patch bordering northern Brazil and extending into southern Suriname, and the smallest and most elongate outlier, that occurs in eastern Brazil north of the Amazon extending from near Macapa to near Calcoene.

The Gran Sabana uplands are gently rolling high plains, formed by sediments of the Roraima Formation, which overlie discordantly the rocks of the Guyana Shield (Dezzeo, 1994). Geologically, the Guiana Shield is an ancient Precambrian land mass (4 billion to 590 million years old) made up of varied formations of sedimentary and igneous origin especially granites and gneisses (Huber, 1995). This basement was formed during different orogenic phases characterized by large and long-lasting tectonic thermal events that occurred repeatedly during Archean and Proterozoic times (Huber, 1995). The Roraima formation consists on pink, yellow and white sandstones, red quarzitess, green, black and red shales, conglomerates and boulder beds (Fanshawe, 1952). Oxisols are frequently found under savanna vegetation (Hubber, 1995). This soil has experienced intense meteorization and high weathering rates, losing aluminium and silicates. The additional low content of organic matter and low capacity of cationic interchange, makes these soils poor in phosphorus and other nutrients (Hernandez, 1987). High accumulations of toxic aluminium compounds have often been measured in the subsoil, which severely affect the nutrient balance of the vegetation growing on them (Fölster, 1986; Huber, 1995).

The northern area of this ecoregion belongs to the eastern basin of the Río Orinoco. This sector is drained mainly by the upper Río Caroní called the Río Kuquenán, the Río Yuruaní, and Río Arabopó. The southern and eastern savannas belong to the Río Branco basin. The rivers of the region are black-water rivers, characterized by their typically low concentrations of electrolytes, with the dark brown colour of the water due to the fluvic acids (Dezzeo, 1994). The extremely low nutrient content of these rivers indicates pronounced nutrient deficiencies in the ecosystems of the area (Briceño and Marti, 1986). This region shows a submesothermic climate (20–24°C). Average temperatures are around 20°C and average rainfalls are between 2,000 and 3,000 mm. There is a weak dry season from December to March in the northern portion. In the Guyana portion at least one dry season occurs in a year and two during most years (Boggan *et al.,* 1997). During most of the year, north-easterly and south-easterly trade winds are predominant in the area. The relative air humidity is generally high in the entire region, with mean annual readings between 75–85% (Dezzeo, 1994).

The plant cover of the Gran Sabana is an intricate mosaic, constituted by numerous types of vegetation. With the exception of the continuous forests at the foot of the Tepuis, forests occur in patches or islands, encircled by extensive grasslands and meadows, as well as by shrub formations (Dezzeo, 1994). The savannas dominated by grasses are essentially free of shrubs and trees; but in some cases, low shrubby or suffruticose elements may be present, thus classifying as shrubby meadows of scrub savannas (Dezzeo, 1994). The most common plant species in the Venezuelan savannas are: *Euphorbia guianensis, Humiria balsamifera, Clusia sp., Calliandra sp., Chamaecrista sp., Bonnetia sessilis, Myrcia sp., Ternstroemia pungens* (scrublands), *Axonopus pruinosus, A. kaietukensis, Trachypogon plumosus, Echinolaena inflexa, Bulbostylis paradoxa, Rhynchospora globosa, Hypolytrum pulchrum* (open savannas), *Hypogynium virgatum, Andropogon sp., Panicum sp., Byttneria genistella, Miconia stephananthera, Mahurea exstiputata and Mauritia flexuosa* (palm savannas), *Chalepophyllum guianense, Digomphia laurifolia, Tococa nitens and Poecilandra retusa* (meadows) (Huber and Alarcon, 1988; Dezzeo 1994). Most of the elements of the flora found in Venezuelan savannas are also present in northern Brazil, Guyana and Surinam (Steyermark, 1977; Boggan *et al.,* 1997).

Biodiversity

As many other savanna regions, the most obvious and recurrent dynamic element in the Gran Sabana is fire, which plays a very important role in the culture of the indigenous people who have lived in the area for centuries (Dezzeo, 1994). Nevertheless, the susceptibility to fire and its lasting effects are not typical of a humid tropical forest environment - these are explained by very particular conditions of ecological instability, such as the reduced ability of the ecosystem to withstand external impacts (fire and extreme droughts), as well as unfavourable internal factors, such as oligotrophic and hydric stress (Folster, 1986). The main consequence of this ecological instability has been originated the gradual – both ancient and recent - degradation of remaining forest, and its substitution by savannas (Worbes, 1999).

In terms of biodiversity, the Gran Sabana has been recognized as an important plant refuge and dispersal centre. Steyermark (1979) reports several endemic plants in the Gran Sabana. Picon (1995, in Huber *et al.,* 1998) registered 204 species including endemic species in Sierra de Lema and Cerro Venamo in the Venezuelan portion. Some of this taxa occur in the open savanna in swamps, on dry rocky terrain, or in the gallery forests or forested quebradas, which at different altitudinal levels traverse savanna landscapes (Steyermark, 1979).

Endemic birds of the Guyanan Highland include 36 totally restricted to the vicinity of the tepui mountains, with most of the endemics found on the Gran Sabana (Huber, 1997). These are primarily montane species occurring in the humid forest on the piedmont slopes above 600 m (Huber, 1997). Some examples are the Tepui Swift (*Cypseloides phelpsi*) that inhabits montane evergreen forest, cliffs, rocky canyon, grasslands and savannas. The Tepui Goldenthroat (*Polytmus milleri*) lives in the forest edge as well as in low, seasonally wet grassland and scrub, and the Tepui Wren (*Troglodites rufulus*) occurs in montane evergreen forest edge, elfin forest, scrub and savanna (Stattersfield *et al.,* 1998).

Compared with the Guyanan Tepuis, the Gran Sabana has a relative low number of endemic anurans, an order of animals in the class Amphibia that includes frogs and toads. Most of the endemic species of this area are restricted to the forest of La Escalera including *Colostetus parkerae, Stefania scalae, Cinax danae, Tepuihyla rodriguenzi*, and *Eleutherodactylus pulvinatus*. *Tepuihyla galani* is found in savannas and certain tepuis (Frost, 1985; Gorzula and Señaris, 1998). Some species found only in savannas are *Scinax exiguus* and *Leptodactylus sabanensis* (Frost 1985; Gorzula and Señaris, 1998).

Current Status

The Gran Sabana fills the entirety of the eastern section of Canaima National Park that cover around 30,000 km2. Mount Roraima National Park in Brazil, covering 1,160 km2, and the Parque Indigena Tucumaque, protect other parts of the Gran Sabana. However, a great area of this ecoregion still remains unprotected and even in protected areas, more effective controls and enforcement of the regulations are needed (Huber, 1997).

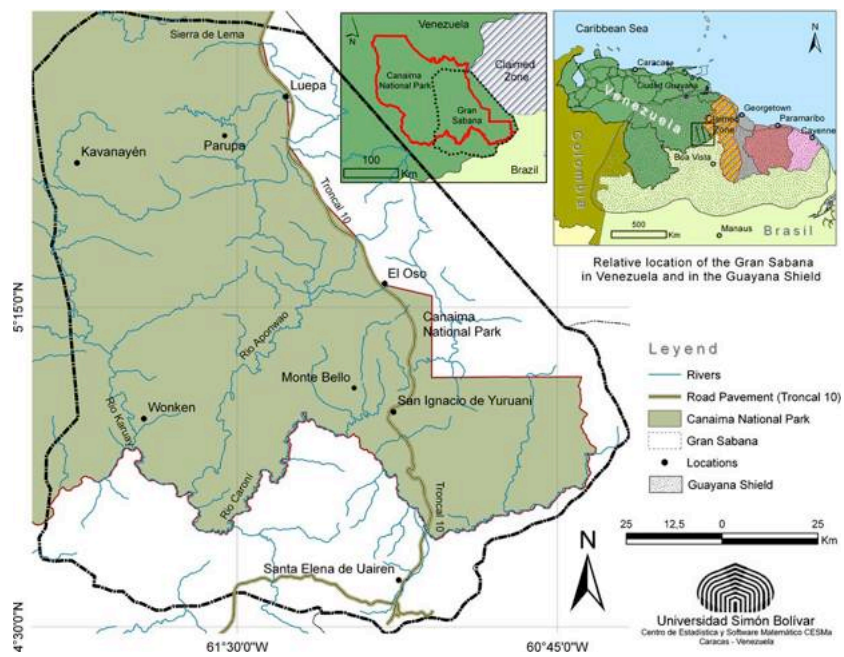
Relationship between Fire and Biodiversity

Degradation of the remaining forests into grasslands, due to natural or intentional fires, is the most important threat to vegetation (Huber, 1996). Habitat fragmentation caused by intense, wide ranging fires results in the gradual extinction of the species that cannot adapt to the degraded habitats (Gorzula and Señaris, 1998). The loss of vegetation cover and soil erosion affects the micro-hydrology of small streams causing them to become intermittent during the dry season. These impacts have caused the decline of amphibians that depend on these microsites (Gorzula and Señaris, 1998).

Vegetation fires form a dense layer of smoke that affect the climatic conditions of the Gran Sabana. This occurrence could create a local greenhouse effect during the hottest time of the year, leading to even hotter conditions and more intensive damage by the fires (Huber, 1995).

Gold and diamond mines are found throughout the region. Although the direct impact on vegetation caused by this activity is usually small, the side effects can be severe. Some of these side effects are mercury pollution, an increase in the sediment load of the rivers, overhunting, and the frequent fires (Huber, 1995). Extensive tourism is already present in Venezuelan savannas. The construction of the paved road from La Escalera to Santa Elena de Uairén, for example, has caused several problems including littering, illegal gathering of plants and animals, and fires (Huber, 1995).

Figure 14. Canaima National Park and the Gran Sabana from (Bilbao et al., 2010)



Traditional Fire Knowledge and Practices

The fire practices of the Pemon peoples of the Gran Sabana have changed in a pattern consistent with many indigenous cultures. Where once wide-ranging across the Gran Sabana and burning in cooperative patterns in small village and clan groups, the populations have become concentrated in larger towns. As a result, fire patterns have changed (Sletto, 2008). The Pemon employed landscape level fuel management practices across the landscape before settlement into larger towns. Before congregation in larger settlements, fuel loads were managed across the savanna landscape, creating various mosaics of time-since fire. These variable patterns of ignitions common in indigenous fire practices throughout this assessment sub-region diminished the probability of widespread severe fires that impact forest resources and fire sensitive species. Currently frequent fires undermine biodiversity goals for the Canaima National Park by expanding savannas into riverine and gallery forests. These vegetation types are not adapted to these more recent fire regimes. This exacerbates relationships between the Permon and Canaima National Park administrators, who adhere to fire exclusion policies (Bilbao *et al.,* 2010, Rodriguez, 2007, Sletto, 2008). Conversely the Pemon see fire use as part of their cultural identity. Like elsewhere and proven extensively in the United States, suppression of fires is ineffective at managing fuel loads and solving "fire problems", with United States suppression costs reaching nearly a billion dollars each year. In the Gran Sabana only about 13% of fires are brought under control by fire-fighters (ENDELCA, 2004). Reduction in indigenous burning on a large-scale has likely resulted in increased fuel loads that result in large-scale historically rare severe fire events (Sletto & Rodriguez, 2012). Recently, (July 2015) workshops have been held with stakeholders and subject matter experts to further understanding and towards the development of shared goals between conservationists, park administrators, scientists and local Indigenous peoples to develop sustainable approaches to fire management in the region.

In terms of the feasibility of SFiM building from the Australian experience, the Gran Sabana contains vast expanses of C4 grasses and fire dependent vegetation with fire sensitive broadleaf and riverine forest systems embedded in a flammable landscape. Late wet season-early dry season fire practices as utilised in the Australian abatement methodologies are likely to be feasible in this sub-region, however further on the ground work is required to build greater readiness for methodology-based SFiM. Avoiding dry season fires in the Gran Sabana could have the potential to reduce emissions, prevent deleterious impacts on fire sensitive ecosystems such as the gallery forestes, and deliver co-benefits to local Pemon populations.

Figure. 15 Fire Detection Data for the Gran Sabana

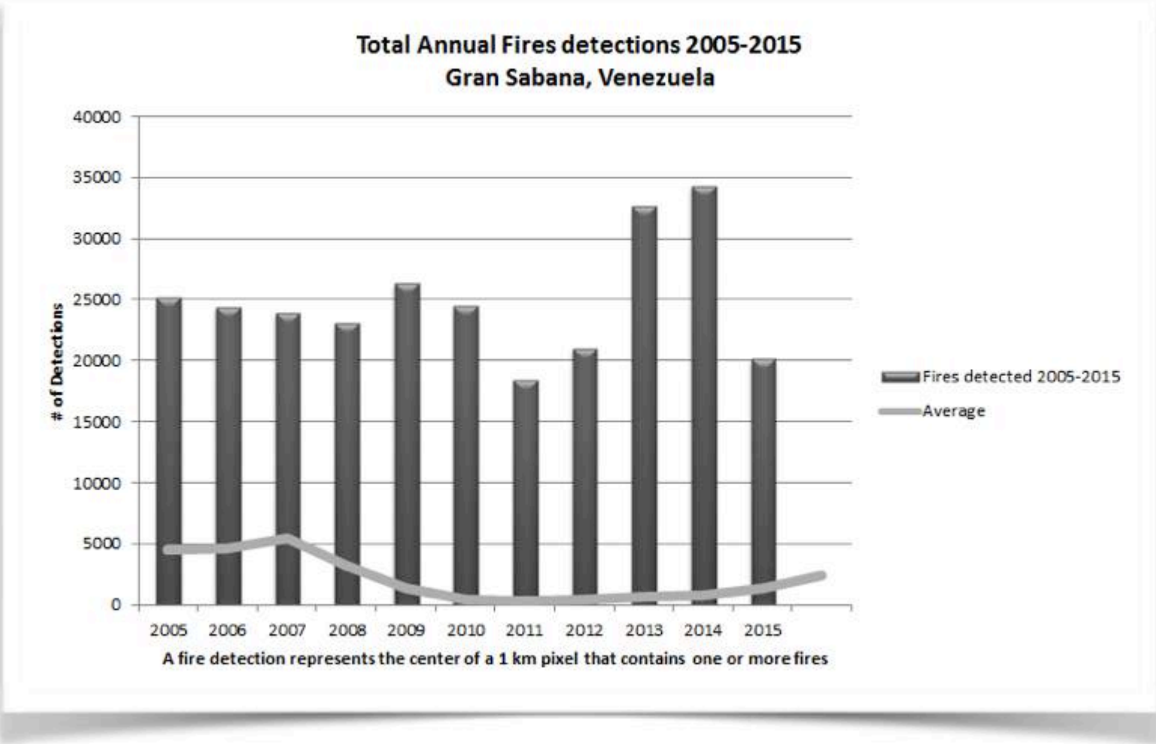
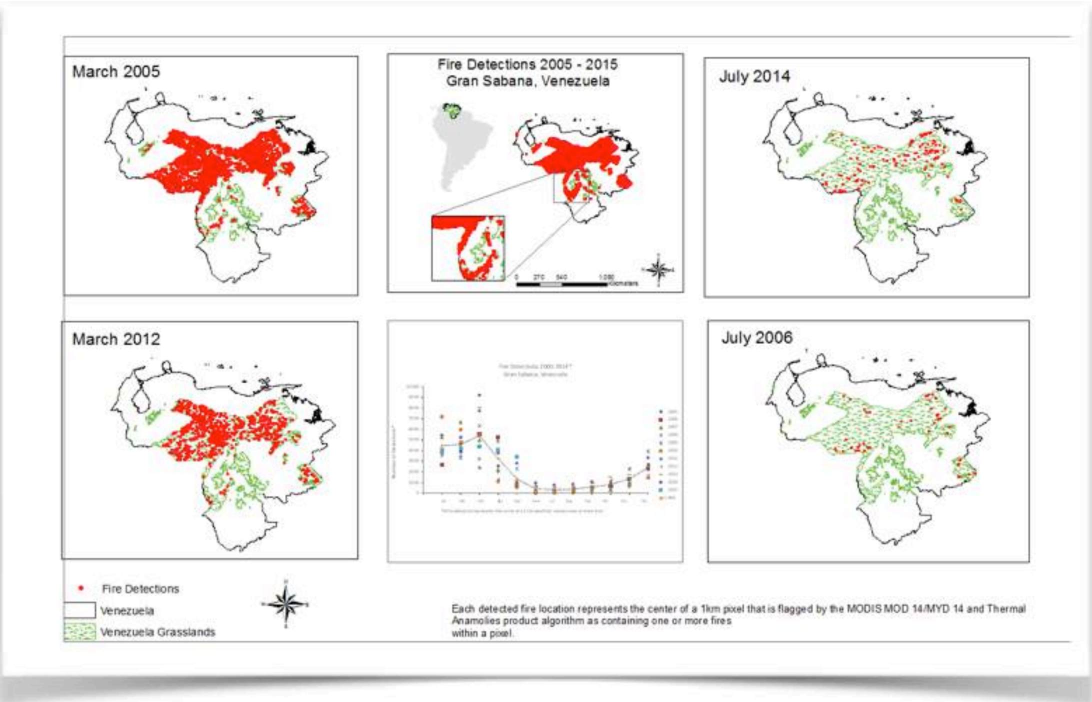


Figure 16. Assessment of Fire and Seasonality in the Gran Sabana



Central America: Belize Pine Savannas

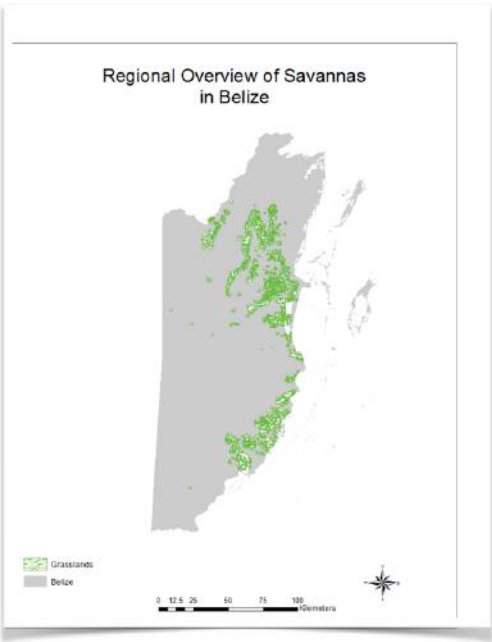
The Belize Pine Savannas represent an example of a small but important tract of savanna, like others found in the Central American and Caribbean region. Critically endangered due to agricultural and aquaculture exapansion and development, the pine forests of Belize on Central America's north-western Caribbean coast represent various relatively preserved fragments of vegetation, with a considerable abundance of fauna. The Belize pine forests represent one of the few examples of lowland and premontane pine forests in the neo-tropics, where the predominant tree species is *Pinus caribaea var. hondurensis*, which requires periodic low intensity burns for its regeneration (Perry, 1991). The vegetation is adapted to the xeric, acidic and nutrient-poor conditions that occur primarily in the dry season (Horwich & Lyon, 1990). The coastal areas of the ecoregion, with vegetation that is less dense, are threatened due to expansion of pineapple citrus and banana plantations, as well as shrimp farming in coastal savannas (Dinerstein *et al.,* 1995, McCarthy & Salas, 1998).

Description

This relatively small ecoregion of less than 3,000 km2 is found mostly in Belize and is included in the zone of wet subtropical forests (more than 2,000 mm of average annual precipitation and no frosts). There are two other patches of this ecoregion in isolated locations in Mexico (southern Quintana Roo) and Guatemala (northeast), which do not appear on the map of Central American ecoregions (Perry, 1991). In Belize there is a relatively large premontane area (about 700 m above sea level), more or less in the centre of the country (western strip of Mountain Pine in the Maya mountains), with closed or semi-closed pine forests, and numerous more irregular and smaller fragments that correspond to pine savanna with varying degrees of forest cover. In the adjacent Maya Mountains, the topography is more rugged and crossed by various rivers, and night time temperatures are lower. The pine trees are larger and numerous, and the pine forest intersects other formations of interest such as rainforest, cohune palm (corozal), cactus associations, and others (International Expeditions, 1992). It is estimated that 11% of Belize is covered by natural pine vegetation. Only 2% corresponds to totally closed forests, 3% to semi-closed forests, and the remaining 6% to pine savannas that occupy coastal areas and contain isolated pine trees and/or groups of pine trees separated by extensive grassland savannas (Harcourt & Sayer, 1996). In addition to human activity, edaphic factors are a determining factor in this distribution. The forests on the northern plain and southern coast are located on sandy soils or sandy-clayey soils and usually have less drainage than the more fertile soils in the centre of the country (Perry, 1991).

In addition to the Caribbean pine (*Pinus caribaea var. hondurensis*) that is characteristic of this sub-region, there are *Crescentia cujete*, some species of oak (*Quercus spp.*), *Curatella* *americana, Byrsonima crassifolia*, and the palms *Acoelorraphe* and *Paurotis wrightii*. The canopy of these pine forests is usually never closed. There are abundant low shrubs and savanna areas with grasses, reeds and numerous common wildflower species. Due to the burning of unprotected areas to attract deer, tree density depends to a great extent on the frequency and severity of fires. It should be noted that fires in mature forests could be beneficial to the trees (Horwich, 1990; Perry 1991). At elevations of 650-700 m., the forests become premontane in terms of vegetation. Representative species are *Pinus oocarpa* (which crosses with *P. caribaea* where their distributions overlap, although belonging to subsections of different genera), *Podocarpus guatemalensis* and *Quercus* spp., and in still wetter areas there is a predominance of *Pinus patula* together with the palm *Euterpe macrospadix* and the arboreal ferns *Alsophila myosuroides* and *Hemitelia multiflora.* (Harsthorn *et al.,* 1984; Harcourt & Sayer, 1996).

Figure. 17. Regional Overview of Savannas in Belize



Biodiversity

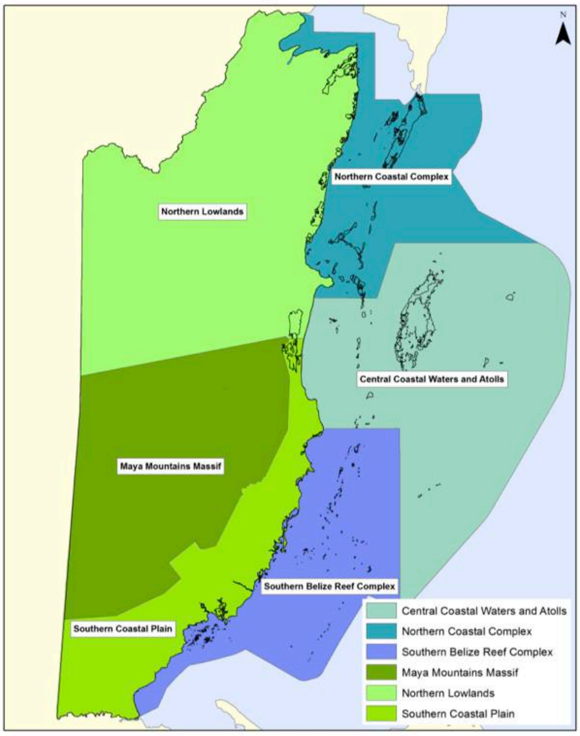
In Belizean savannas the presence of elements of the flora and fauna of both North and South America merge. In terms of flora, there are few endemisms in the region (Hartshorn *et al.,* 1984) although there are some interesting adaptations. *Pinus caribaea,* for example, depends on periodic low-intensity burns regeneration. On the coasts, interior lakes and rivers of Belize, and, by extension, in this ecoregion, there are two species of threatened crocodiles, *Crocodylus acutus* and *C. moreletii*.

There are two endangered bird species in Belize (Collar *et al.,* 1992) of conservation interest whose survival is tied directly to fire regimes and pine forests. One of them, the yellow-headed parrot (*Amazona oratrix*) lives in this ecoregion and depends upon old, large diameter pines to nest. These parrots require open fire maintained systems. Of particular interest is the presence of Central America's highest procreative colony of jabiru (*Jabiru mycteria*), a large migratory bird, particularly in the Crooked Tree sanctuary, on the country's northern savannas. Also to be noted is the use of this habitat by the Mexican black howler (*Alouatta pigra*), which can be considered the most endangered howler monkey of the genus, and the Central American spider monkey (*Atteles geoffroyi*). Both species experienced a decline due to the epidemic yellow fever that swept the country in the 1950s (Horwich 1990). The five feline species that exist in Belize: jaguar (*Panthera onca*), puma (*F. concolor*), ocelot (*Leopardus pardalis*), margay (*Leopardus wiedii*) and yaguarundí (*Herpailurus yagouaroundi*) are in appendix I of CITES, as well as the Central American tapir (*Tapirus bairdii*), which can been seen with relative frequency. Belize has the highest density of felines in Central America (Carrillo *et al.,* 1994). The tapir is abundant around rivers. The white-lipped peccary (*Tayassu pecari*) in Appendix II of CITES, is also distributed in the region.

Current Status and Threats

This pine forest ecoregion is important at the regional level and generally considered to have a relatively stable conservation status (McCarthy & Salas, 1998), although there are no concrete figures for determining the ecoregion's conservation status because no high-quality data is available (Dinerstein *et al.,* 1995). Only 25% of the pine savanna areas are found in protected areas. The regions around the central fragment are also protected. Sustainable lumber operations are being carried out in the reserve in the Mountain Pine strip as well as the Deep River Forest Reserve. If this activitity continues at present rates, it could ensure a long-term domestic supply of soft wood (Harcourt & Sayer, 1996). The protected areas are relatively large compared to the area occupied by the ecoregion as a whole, and the protection system is one of the best in the region.

Figure18. Belize Protected Area Zones: The Southern Coastal Plain is the location of large savannas and rural Maya populations. Note the connectivity from Mountains to Reef.



Due to increasing migration from adjacent countries and expanding agriculture, fire frequency is increasing in dry season and fire size is expanding. Crop losses due to wildfire from dry-season ignitions from hunters and farmers threaten the reproduction of pine species, killing seedlings and impacting the future of existing sustainable logging operations and the future habitat of the endangered yellow-headed parrot. Severe fires during the dry season induce mortality in adjacent broadleaf ecosystems. Dry-season savanna fires reach into the fire-sensitive vegetation on the slopes of the Maya Mountains causing soil erosion to Kechi and Mopan Maya villages, degrading soils used for milpa farming and impacting water quality. Long-term regional haze produced by long-duration fires and burning of forest soils is impacting upon public health and air quality. Dry season and ensuing anthropogenic fires obscure scenic views, undermine visitor experience and ultimately reduce visitor numbers, resulting in economic losses to Mayan people, and the nation as a whole. Increasing numbers of Guatemalan and other immigrants from nearby countries, accustomed to consuming wildlife species and clearing unoccupied wild lands for agriculture, have also exacerbated problematic fires and impacted biodiversity, although maximum efforts have been made to keep agriculture confined only to those lands that are most suited to this purpose ,(Carrillo &Vaughan, 1994).

Biodiversity in Belize is threatened by deforestation as a result of illegal logging and encroachment, wildfires, and slash-and-burn agriculture. The impact of productive activities on biodiversity and on the overall environment is reflected in changes in land use, with forest area converted to agricultural use or replaced by forest plantations. These changes in land use result in habitat destruction, soil erosion, water source contamination, ecosystem fragmentation and species loss. At the same time, because most of these producers (and communities) are impoverished and marginalized, their management decisions are often heavily influenced by short-term economic needs (i.e. relative prices of different crops), which frequently ignore long- term sustainability issues and environmental concerns.

Income generating activities from the use of natural resources are important contributors to biodiversity loss. Belize's protected areas are a major asset to the national economy, contributing hundreds of millions of dollars in ecosystem goods and services each year (Drumm *et al.,* 2012). Protected areas play a major role in maintaining the base of the Belizean economy. The tourism industry, which generates nearly a quarter of Belize's gross domestic product (GDP), is largely dependent on protected areas. Furthermore, the timber industry is sustained by the PA system.

Fire Characteristics and Impacts in Belizean Savanna

As described, like many savannas those of Belize are fire adapted C4 grasslands (Bond and van Wilgen, 1995) with scattered pine, hardwood trees, and shrubs. Plant diversity reaches optimum diversity with frequent fire return intervals (1-3 years) of relatively low intensity. Reduced frequency allows vegetation to rebound or at times escape burning within refugia created by wet season mosaic burning. Currently, large-sale severe fires occurring during the late dry season characterise the modern fire environment. Latin America Figures 19 – 21 illustrate fire detections, and 22 illustrates annual temperature. Latin America Figure 23 provides approximate emissions values, noting that these are rudimentary and that a need remains for improved on-the-ground monitoring & detection.

The observable effects of wet season fires on biological diversity include increased flowering and fruiting in herbaceous species, little or minor mortality of Caribbean Pine seedlings, mid-canopy regeneration and the presence of old-growth individuals. Late dry season fires on the other hand incinerate palmetto flowers and other fruits harvested from the savannas for cash incomes by neighbouring Maya communities. Severe dry-season fires are lethal to the pine seedlings that are replenishment stocks for yellow-headed parrot habitat as well as future timber resources for thirty-year logging leases such as Tomas Gomez and Sons LTD. High intensity fire during the May nesting season of avian species as well as for mammals and amphibians induce direct mortality on nests, young and available foraging and nesting habitat loss. The highly endangered yellow-headed parrot that depends upon the old-growth Carribbean pines of the Belizean Savanna often faces direct mortality from intense wind driven dry-season wildfires. In early dry season fire regimes low flame length and patchy mosaic burning poses little risk to yellow-headed parrots. Late dry season fires also coincide with nesting and reproductive cycles of native Belizean avifauna and wildlife. Organic soil loss due to long-term combustion (smouldering) only occurs during the driest season and has become more widespread and pervasive as fire frequency and severity has increased.

Loss of key biological diversity areas such as large, adjacent broadleaf forests is increasing, and impacts upon a suite of forest species are generated by these historically rare severe fires. Though savannas depend on appropriate fire regimes, adjacent broadleaf forests found on slopes, and river forests, are impacted negatively by fire. Sediment from soil erosion displaced by high temperature fires flows into mangrove zones and into the largest reef in the western hemisphere. The impact upon water quality, both fresh and estuarine, is unknown.

Large-scale dry season fires also impact regional air quality, impacting tourism and public health with many days of low visibility and poor air quality in both urban and rural populations. Small Maya villages and other rural populations are directly affected by high levels of regional haze due to wildfires. The magnitude of the impact upon health and public safety is unknown.

Figure 19. Fire Detections in Belize

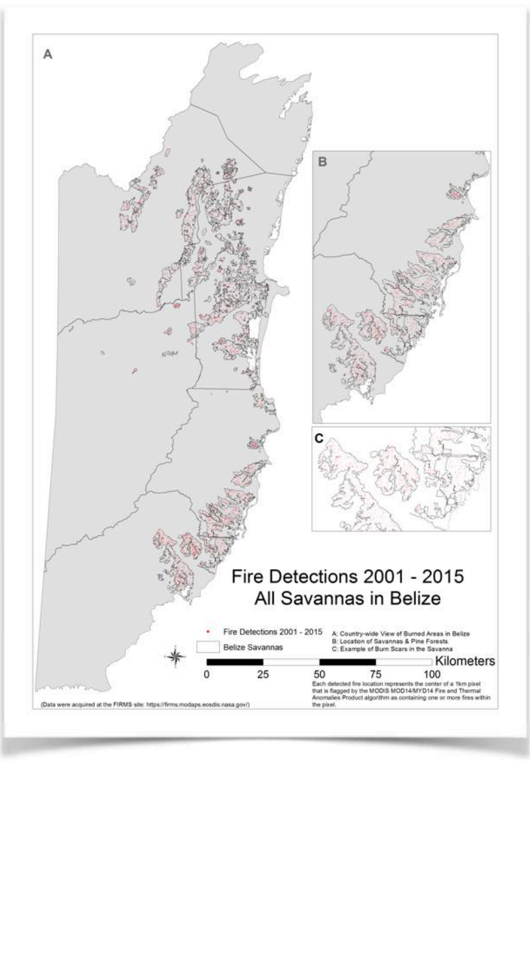


Figure 20. Annual Fire Detections Belize

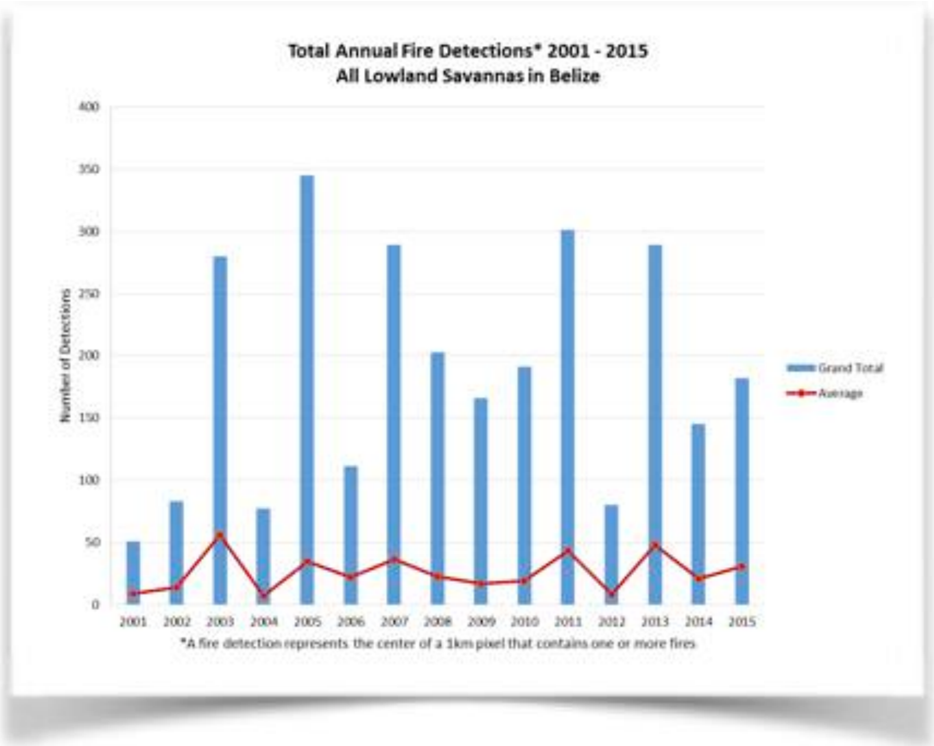


Fig 21. Monthly Fire Detections Belize

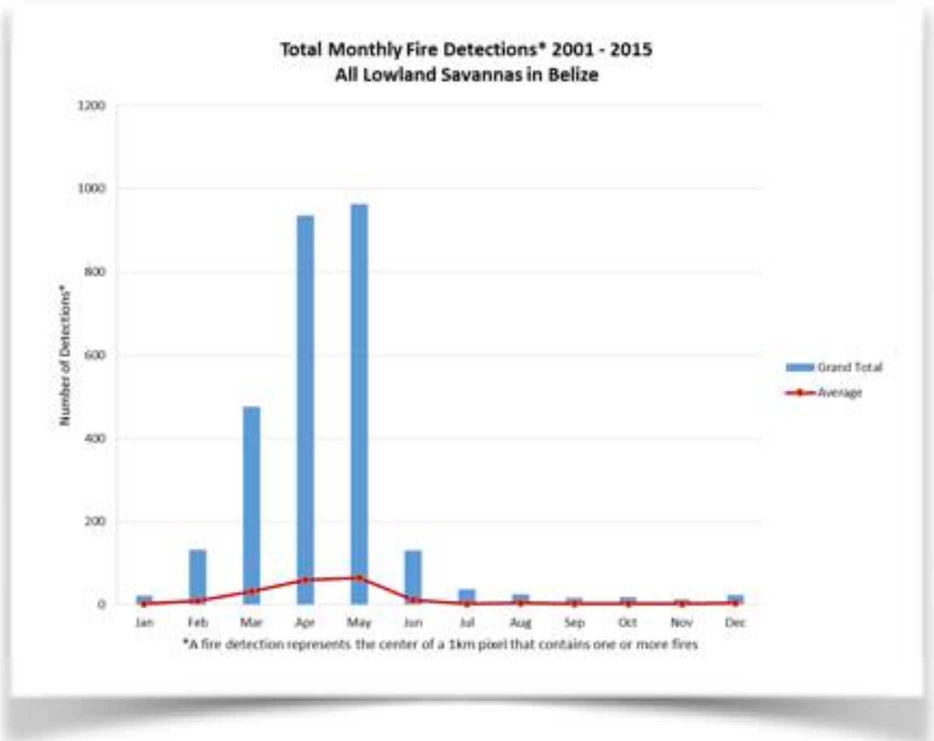


Figure 22. Average Temperature and Precipitation Belize

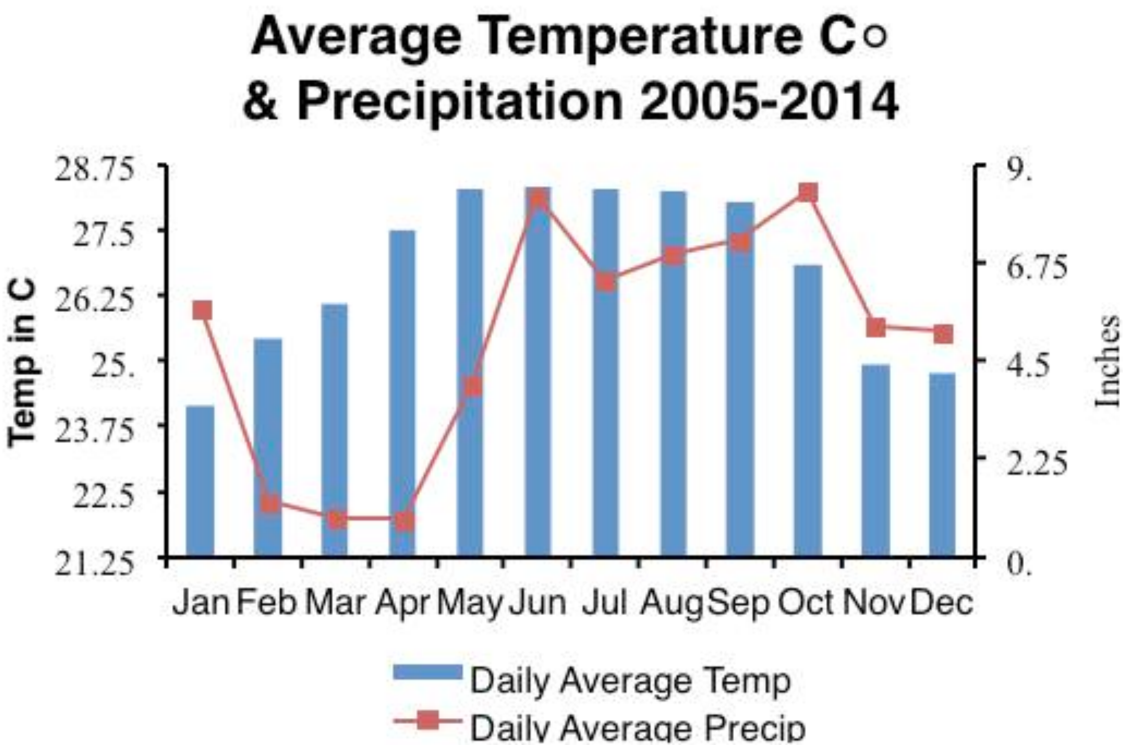

Average Temperature C○
& Precipitation 2005-2014
Temp in C
28.75
27.5
26.25
25.
23.75
22.5
21.25
9.
6.75
4.5
2.25
0.
Inches
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Daily Average Temp
Daily Average Precip

Fig 23. Belize Pine Savannas Emissions: tonne Carbon Equivalent.

These values represent tonnes of Carbon Dioxide equivalents (t.CO2•e) are derived for each month 2001-2015 for Belize, based on the FIRMS detections, where each detection indicated a 100ha pixel with fire in it. We used a high fuel load (GR6) & a low fuel load (GR3) to estimate the values for fuel loads. High patchiness areas assume only 25% of a 100ha pixel burned, low patchiness areas assume 75% of a 100ha pixel burned. Wet season fuels availability is 25% of the total available fuels (as derived using the GR3 & GR6 fuel loads; total available fuels were 4.48 (GR3) & 7.85 tonne/ha (GR6)). These give some rough estimates for emissions values, but indicate the need for on the ground monitoring & detections. Each tonne of CO2-e abated is equivalent to 1 carbon credit.

Fuel Load	tonne/ha
GR3 = 2.0 t/ac	4.48
GR5 = 2.9 t/ac	6.50
GR6 = 3.5 t/ac	7.85

	GR3	GR5	GR6
BEF	*tonne/ha*	*tonne/ha*	*tonne/ha*
25% available (Wet Season)	1.12	1.63	1.96
50% available	2.24	3.25	3.92
75% available	3.36	4.88	5.88
100% available (Dry Season)	4.48	6.50	7.85

High Patchiness (25% of Total Area Burned) --CH4 Emission (t.CO2-e)								
	High Patchiness, Wet Season, GR3		High Patchiness, Dry Season, GR3		High Patchiness, Wet Season, GR6		High Patchiness, Dry Season, GR6	
	Grand Total	Monthly Average	Grand Total	Monthly Average	Grand Total	Monthly Average	Grand Total	Monthly Average
Jan	12946	863	51783	3452	22655	1510	90621	6041
Feb	70519	4440	282078	17760	123409	7770	493636	31081
Mar	82359	18509	329436	74037	144128	32391	576513	129565
Apr	107833	33809	431331	135236	188707	59166	754830	236662
May	180447	43010	721788	172040	315782	75268	1263130	301071
Jun	361194	6794	1444777	27176	632090	11889	2528360	47557
Jul	682416	963	2729662	3852	1194227	1685	4776909	6740
Aug	1735852	963	6943410	3852	3037742	1685	12150967	6740
Sep	2677037	695	10708149	2782	4684815	1217	18739261	4868
Oct	1207510	695	4830040	2782	2113142	1217	8452569	4868
Nov	204791	481	819165	1926	358385	843	1433538	3370
Dec	84842	909	339369	3638	148474	1591	593896	6366
Grand Total	*7407747*	*109569*	*29630988*	*438275*	*12963557*	*191745*	*51854230*	*766981*
Annual Average 2001-2015	*617312*	*9344*	*2469249*	*37378*	*1080296*	*16353*	*4321186*	*65411*

Low Patchiness (75% of Total Area Burned)--CH4 Emission (t.CO2-e)								
	Low Patchiness, Wet Season, GR3		Low Patchiness, Dry Season, GR3		Low Patchiness, Wet Season, GR6		Low Patchiness, Dry Season, GR6	
	Grand Total	Monthly Average	Grand Total	Monthly Average	Grand Total	Monthly Average	Grand Total	Monthly Average
Jan	38837	2589	155350	10357	67966	4531	271862	18124
Feb	211558	13320	846233	53281	370227	23311	1480908	93242
Mar	247077	55528	988308	222112	432385	97174	1729538	388696
Apr	323498	101427	1293994	405707	566122	177497	2264489	709987
May	541341	129030	2165365	516121	947347	225803	3789390	903212
Jun	1083583	20382	4334332	81527	1896270	35668	7585081	142672
Jul	2047247	2889	8188986	11555	3582682	5055	14330726	20221
Aug	5207557	2889	20830230	11555	9113225	5055	36452902	20221
Sep	8031112	2086	32124448	8345	14054446	3651	56217784	14604
Oct	3622530	2086	14490119	8345	6339427	3651	25357708	14604
Nov	614373	1444	2457494	5777	1075154	2528	4300614	10111
Dec	254527	2728	1018107	10913	445422	4774	1781687	19098
Grand Total	*22223241*	*328706*	*88892965*	*1314825*	*38890672*	*575236*	*155562689*	*2300944*
Annual Average 2001-2015	*1851937*	*28033*	*7407747*	*112133*	*3240889*	*49058*	*12963557*	*196233*

High Patchiness (25% of Total Area Burned) --N2O Emission (t.CO2-e)								
	High Patchiness, Wet Season, GR3		High Patchiness, Dry Season, GR3		High Patchiness, Wet Season, GR6		High Patchiness, Dry Season, GR6	
	Grand Total	Monthly Average	Grand Total	Monthly Average	Grand Total	Monthly Average	Grand Total	Monthly Average
Jan	191105	12740	764420	50961	334434	22296	1337735	89182
Feb	1041001	65544	4164004	262177	1821752	114702	7287008	458810
Mar	1215775	273233	4863101	1092931	2127607	478157	8510427	1912629
Apr	1591818	499084	6367271	1996337	2785681	873397	11142725	3493589
May	2663743	634911	10654973	2539643	4661551	1111094	18646202	4444376
Jun	5331917	100291	21327666	401163	9330854	175509	37323416	702035
Jul	10073753	14214	40295012	56858	17629068	24875	70516271	99501
Aug	25624489	14214	102497955	56858	44842855	24875	179371421	99501
Sep	39518170	10266	158072681	41064	69156798	17965	276627192	71862
Oct	17825146	10266	71300584	41064	31194005	17965	124776021	71862
Nov	3023107	7107	12092430	28429	5290438	12438	21161752	49750
Dec	1252433	13425	5009731	53699	2191757	23493	8767029	93973
Grand Total	*109352457*	*1617443*	*437409829*	*6469773*	*191366800*	*2830526*	*765467200*	*11322103*
Annual Average 2001-2015	*9112705*	*137941*	*36450819*	*551765*	*15947233*	*241397*	*63788933*	*965589*

Low Patchiness (75% of Total Area Burned)--N2O Emission (t.CO2-e)								
	Low Patchiness, Wet Season, GR3		Low Patchiness, Dry Season, GR3		Low Patchiness, Wet Season, GR6		Low Patchiness, Dry Season, GR6	
	Grand Total	Monthly Average	Grand Total	Monthly Average	Grand Total	Monthly Average	Grand Total	Monthly Average
Jan	573315	38221	2293260	152884	1003301	66887	4013205	267547
Feb	3123003	196633	12492013	786531	5465256	344107	21861023	1376430
Mar	3647326	819698	14589304	3278793	6382820	1434472	25531282	5737888
Apr	4775454	1497252	19101814	5989010	8357044	2620192	33428175	10480767
May	7991230	1904733	31964919	7618930	13984652	3333282	55938607	13333128
Jun	15995750	300872	63982999	1203488	27992562	526526	111970248	2106104
Jul	30221259	42643	120885036	170573	52887203	74626	211548814	298503
Aug	76873466	42643	307493865	170573	134528566	74626	538114263	298503
Sep	118554511	30798	474218043	123192	207470394	53896	829881576	215585
Oct	53475438	30798	213901751	123192	93582016	53896	374328064	215585
Nov	9069322	21322	36277290	85287	15871314	37313	63485257	149251
Dec	3757298	40274	15029193	161097	6575272	70480	26301087	281919
Grand Total	*328057372*	*4852330*	*1312229486*	*19409320*	*574100400*	*8491577*	*2296401601*	*33966309*
Annual Average 2001-2015	*27338114*	*413824*	*109352457*	*1655296*	*47841700*	*724192*	*191366800*	*2896768*

Traditional Fire Knowledge and Practices and Impact of Current Fire Regimes on Indigenous Livelihoods

The Maya are the country's indigenous population. They are the direct descendants of the original indigenous inhabitants of the Yucatan peninsula. The three Maya groups in Belize are the Yucatec, Mopan, and Q'eqchi' Maya. Mopan Maya settlements are located in San Antonio village in Toledo District within and adjacent to the fire-prone pine savanna of southern Belize.

Q'eqchi' Maya inhabit the lowland savanna areas along rivers and streams and have established 30 small isolated villages throughout Toledo district within the matrix of pine savanna and broadleaf forests at the foot of the Maya Mountain range. Because of their isolation, Q'eqchi' have remained the country's poorest and most neglected minority. Belize's Maya are mainly subsistence farmers using fire to prepare "milpa" for corn and other substance foodstuffs along with burning of savanna for hunting. The Maya have experienced continued encroachment on their lands by non-indigenous settlers and large-scale logging and petroleum enterprises that threaten their traditional territories and way of life.

The Maya of southern Belize experienced a harsh history of colonisation especially in relation to the lands and resources that they have traditionally used and occupied. Many of these lands include the Forest Reserve System and other protected areas. In October 2000 Maya leaders and government signed the 'Ten Points of Agreement,' in which the government recognized Maya rights over traditional lands and resources in general terms, and committed to embark on a set of initiatives to make that recognition effective. This is still mostly unrealised.

Mayan peoples are skilful in their use of fire for hunting and the establishment of Milpa farming practices. Milpas are prepared in January and February by cutting down trees and brush over a relatively small are of a few hectares (Nigh, 2008). The vegetation cures and dries in the sun until burned in April, the early portion of the dry season. Historically, the nearby broadleaf forests would be relatively hydrated and less susceptible to fire spread form milpa fires (Dunning, 1998).

As resources have become scarce and in the face of increasing populations, farmers have attempted to increase production by burning and preparing additional sites later in the dry season. Because of the accumulated effect of increased drying and lack of rainfall, these fires sometimes escape into nearby savanna and broadleaf areas often causing severe large-scale fires. These fires consume organic soils that are combustible in late-dry season thereby impacting future crops. Fires travel upwards across the terrain into fire-sensitive vegetation on the slopes of the Maya Mountains.

The impacts upon water quality and ensuing soil displacement are easily observable. Regional air quality is diminished, creating a potential for health impacts. During the wildfire season of 2015, farmers in the Maya village of Trio in Southern Belize lost hundreds of acres of citrus, banana, cacao and pineapple during one fire event due to uncontrolled wildfire emanating from late season milpa burning.

Impacts upon important forest products are evident. Maya depend for cash income such as palmetto berries that are destroyed by late dry season fires. Early dry-season/late wet season fires encourage palmetto flowering and abundance. Late season fires incinerate berry crops thus impacting household incomes. Frequently severe, large-scale dry season fires induce high levels of mortality in pine seedlings and reduce re-generation of these species. While adult trees often survive fire, seedlings are vulnerable, thus decreasing recruitment for future stocks for the sustainable logging that employs many Maya in the area (Tomas Gomez, Gomez and Sons Logging LTD personal communication, 2015). Severe fast moving fires trap and kill many young and vulnerable animals that the Maya depend such as turkey, deer and agouti.

Communities living within and adjacent to pine savannas in southern Belize have become concerned about wildfire in recent years, due to the considerable damage wildfires have caused to crops and timber resources.

Fig 24. Public Meeting May 20th 2015 in the Maya Village of Trio Toledo District, Belize. Residents are concerned over nearby large-scale fires destroying crops and covering villages with smoke. Belize fire managers explain the benefits of traditional early dry-season fires to the population. May is one of the driest months of the year in Southern Belize.

Potential and Readiness for SFiM in Belize

- Belize has in place policies and plans that endorse the idea of achieving verifiable emissions reductions through wildfire management, but lacks the resources to implement them. In particular, the 2009 Wildland Fire Management Policy and Strategy for Belize remains largely unimplemented due to a lack of resources. Among the principles guiding the development of the Strategy are: 1) that improved wildfire management should enhance opportunities for sustainable livelihoods (Principle 1); 2) that successful fire management requires participatory approaches involving multiple stakeholders (Principle 8), and 3) that the interactions between climate change, vegetation cover and fire regimes should be understood and considered (Principle 5). Aspects of the latter principle include that carbon storage in ecosystems should be maximized and that GHG emissions resulting from fire should be minimized by restoring ecologically appropriate fire regimes. The Strategy recognizes the value of indigenous knowledge. The incorporation of indigenous knowledge into the management of controlled fires is a priority action (Action 1.1.3).
- As a further general indicator of governmental interest in and commitment to improved fire management, the preparation of a REDD+ Readiness Preparation Proposal by the Ministry of Forestry, Fisheries and Sustainable Development demonstrates the Government of Belize's commitment to reducing emissions from deforestation and forest degradation, and to carbon finance as a mechanism for achieving this.
- Indigenous communities in the region are interested and engaged in improved fire management, particularly to control the impact of uncontrolled fire on their livelihoods.
- Baseline data are available on the frequency, extent and intensity of wildfire in and around the savannas of southern Belize, although noting some limitation in historical data.
- Baseline data are available on carbon stocks in the savannas of southern Belize and adjacent ecosystems affected by savanna fires.
- At present, there is no methodology for verifying carbon stocks or emissions from Belizean pine savannas. This would require development and testing. Local organisations have trained 10 local people to conduct forest carbon stock assessment for broadleaf forest and carried out a carbon stock assessment for its private protected area.

- The Southern Belize Fire Working Group members, in particular the two NGOs, have begun to mobilize significant capacity in remote sensing and GIS, although at present they are highly dependent on foreign staff, volunteers and research partners. The organisation TIDE is currently partnering with Dr. Neil Stuart of the University of Edinburgh to establish baseline information on wildfire and forest resources in Toledo's pine savannas using a combination of ground observation, and GIS analysis of Worldview Data from 2011 with a resolution of approx. 1 m in panchromatic and 2 m in multispectral bands.

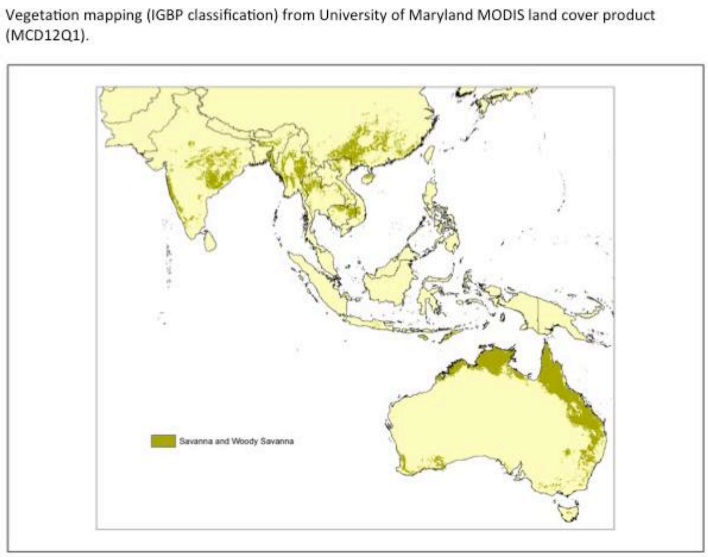
The priority site pre-feasibility assessment for the pine savannas of Belize explores the potential, readiness and steps required for methodology-based SFiM further. While there is a great deal of work to be done, initial indicators of country and community demand, and potential feasibility, are evident.

PART IX – ASIA

Regional Overview

The United Nations (UN) takes a very broad geographical definition of Asia as a grouping of 57 countries throughout the Asia-Pacific region, from Lebanon to the Pacific Island states (http://www.un.org/depts/DGACM/RegionalGroups.shtml). The present investigation addressed a region encompassing 25 countries, broadly spanning from India in the west to some Pacific Island states in the east (Fig. 24; Table 1).

Figure 24 Savanna and woody savanna vegetation in the Asia assessment region.



In particular, this assessment focuses on the relatively fire-prone areas in the Southeast Asia (SEA) region.

From the outset it is important to acknowledge considerable challenges in the undertaking of this assessment, particularly:

- the lack of reliable vegetation and associated land use mapping that accurately depicts the distribution of savannas and savanna-like formations;
- the lack of reliable fire mapping and associated emissions data;
- with regards to people's fire management practices, an available literature focuses mostly on swidden (or 'slash and burn') agroforestry practices in forested settings, but therse is very sparse documentation of allied activities and practices in regional savannas;
- the absence of legislative and regulatory frameworks in any of the major SEA countries that are supportive of traditional fire management activities as part of local traditional swidden agroforestry practices.

These matters are addressed in turn. Importantly, the challenges posed by the scarcity of data applicable to the region do not negate the potential for SFiM to contribute to environmental goals and sustainable livelihoods in the region. As will be demonstrated, there is a strong case for improved SFiM in Asia, and SFiM has the potential to positively impact millions of lives across the region. Nevertheless, they do point to the need in the Asian context for further empirical research and other tools that can transform this potential into practice.

Savannas in the 'Asia' assessment region

Taking the accepted definition of 'savanna' as grasslands (dominated by grass species utilizing the C_4 photosynthetic pathway) with varying densities of tree cover (see Ratnam *et al*., 2011), there is no available detailed classification or reliable fine-scale mapping of the distribution of Asian mixed tree-grass systems (Sankaran & Ratnam, 2013). Apparently, the best available mapping of constituent regional savannas is that of Blasco *et al.,* (1996), as included in Sankaran & Ratnam (2013), and reproduced here as Asia Fig. 25.

Figure 25 Distribution of savanna vegetation in SEA

Source: Sankaran & Ratnam 2013

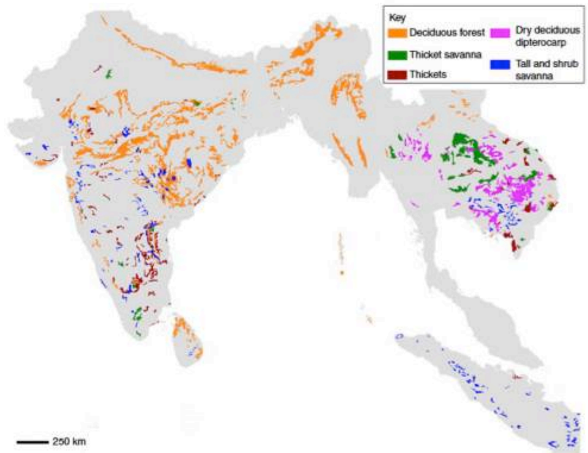


Figure 7 Present day extent of mixed tree–grass vegetation in continental south and Southeast Asia at a scale of 1 : 5 million. The areas in gray represent non-savanna habitats including agricultural lands (Redrawn from Blasco F, Bellan MF, and Aizpuru M (1996) A vegetation map of tropical continental Asia at 1 : 5 million. *Journal of Vegetation Science* 7: 623–634, with permission from John Wiley & Sons; Map credit: Varun Varma).

Sankaran & Ratnam (2013) note that this lack of recognition of savannas in the Asian and Southeast Asian region reflects a strong historical 'forest' bias in available vegetation classification systems. A consequence of this nomenclatural bias is that it has "contributed to the widespread perception that all of the open, savanna-like formations in the region today are derived, that is, they were originally forests that have been converted to savannas as a result of human activities and disturbances such as fire and grazing" (ibid: 68). Sankaran & Ratnam (2013) describe a number of natural savanna types, occurring generally in regions receiving 500 – 2000 mm yr^{-1} rainfall and under dry season conditions of at least 5 months without rain. Neither Blasco *et al.,* (1996) nor Sankaran & Ratnam (2013) provide any breakdown of the extent of constituent savanna types.

More generalized vegetation or 'land cover' mapping products are available, mostly at global scale, which may be used to broadly describe the regional distribution of 'savanna' types. A number of these were consulted and, while all have limitations based on experience with Australian and adjacent regions, here the University of Maryland's MODIS-derived (500 m pixel) land cover product (MCD12Q1; http://glcf.umd.edu/data/lc/) (Friedl *et al.,* 2002), has been applied, since: (a) it uses a directly relevant classification system based on International Geosphere-Biosphere Programme (IGBP) land cover categories, including those describing 'woody savannas', 'savannas', 'grasslands' (refer Table 1 for definitions); and (b) this same classification is used in the most authoritative regional assessment of greenhouse gas (GHG) emissions from biomass burning, including from savannas (van der Werf *et al.,* 2010).

Based on the MCD12Q1 mapping product, the indicative distribution of 'typical' savannas with tree cover >10% is given for the assessment region as a whole with Australia included for reference (Fig. 24). The proportion of typical 'savanna' vegetation (grasslands, savannas, woody savannas) occurring in respective large Asian countries (as well as Australia for reference) is given in Table 1. Countries with proportionally large 'savanna' extents include: Timor-Leste (38.5%, mostly woody savannas); China (38.4%, mostly grasslands); Afghanistan (33.4%, grasslands); Cambodia (30.9%, mostly woody savannas); Myanmar (26.9%, mostly woody savannas); Nepal (24.6%, grasslands).

A fine-scale (50 m resolution) 'forest cover' map for SEA recently has been compiled (Dong *et al.,* 2014); but this does not differentiate finer categories for different 'forest types', nor within the other major mapped 'croplands' class. However, the paper does show promise for finer-scale vegetation mapping in the SEA region into the future.

Savanna fires and emissions in the 'Asia' assessment region

The extent and frequency of biomass burning fires in the assessment region is undertaken here with reference to the global fire-mapping product (MCD4561) derived from MODIS imagery (500 m pixels), for the period 2000-2013. This product is produced monthly, and is available through the USA Geological Survey (USGS) Earth Resources Observation and Science Centre (EROS) (http://lpdaac.usgs.gov).

The distribution and frequency of biomass burning fires over the period 2000-2013, derived from the MCD4561 product, is given in Asia Fig. 26 for the broader Asian assessment region, including Australia for reference. The map illustrates that substantially more burning occurs across northern Australia than in Asia. A closer look at fire patterning in continental

SEA with reference to IGBP 'savanna' and 'woody savanna' land cover classes, is given in Asia Fig. 27.

Figure 26 Fire extent and frequency 2000-2013 in the broader Asian assessment region

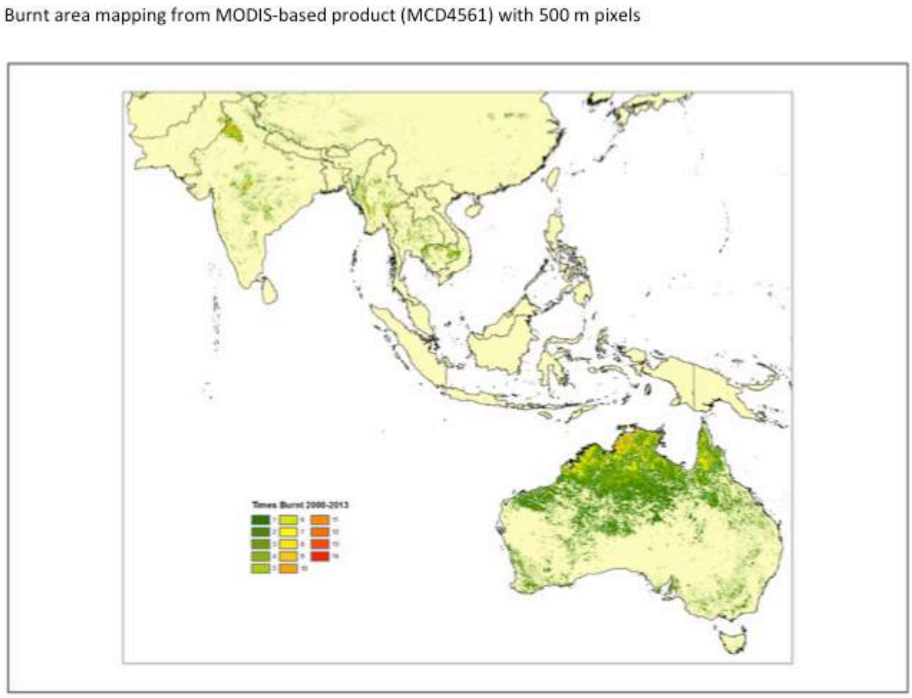
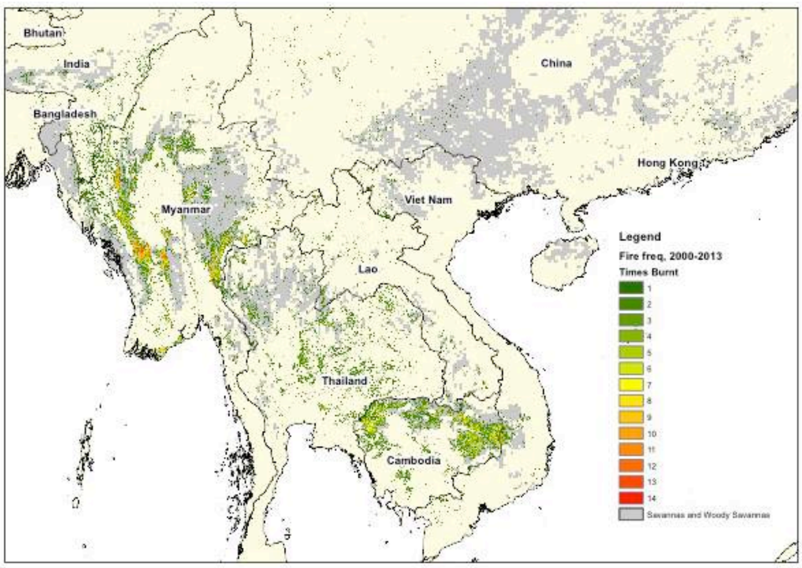


Figure 27 Fire frequency and 'savanna' vegetation in continental Southeast Asia assessment region. Vegetation mapping (IGBP classification) from University of Maryland MODIS land cover product (MCD12Q1). Burnt area mapping from MODIS-based product (MCD4561) with 500m pixels.



The mean annual frequency of burning in savanna land cover classes for larger Asian assessment region countries is given in Table 1. Note that mean fire frequencies given in Table 1 have been multiplied by 100 as values were typically very low, and that these need to be divided by 100 in order to calculate actual frequencies. For illustration, a mean annual frequency of 0.0171 (after dividing by 100) for 'woody savannas' in Laos (Table 1), effectively means that the mean fire-return-period for this land over unit is a fire every ~60 years (i.e. 1/0.0171). Within SEA, savannas in Cambodia and Myanmar are the most fire-prone, with mean fire frequencies of 0.127 (return period ~8 yrs.) and 0.0684 (return period ~14 yrs.), respectively (Table 1).

However, these regional-scale fire mapping data are likely to substantially under-report actual fire extents and frequencies in typical savanna habitats in the assessment region. Randerson *et al.,* (2012) attempted to correct for the influence of small fires that previously had not been detected using another 500 m MODIS burnt area mapping product (MCD64A1), and found that fire extent estimates increased by 157% in insular SEA, and by 90% in continental SEA, over the ten-year assessment period 2001-2010. Similarly, Fisher & Edwards (2015) found that both MODIS MCD64A1 and especially MCD4561 products substantially under-reported the extent of fires by ~50% when fire sizes occupied <15% of a 500 X 500 m MODIS pixel.

In a recent review of fire mapping requirements for monitoring biomass burning primarily in forested, degraded forest, and wetland conditions in insular SEA, Miettinen *et al.,* (2013) recommend that high resolution (<30 m) spatial imagery (e.g. SPOT, Landsat) is essential given that, based on their assessment, 65% of fires in non-wetland situations are <0.25 km^2. They concluded that (ibid.: 4344): "monitoring methods currently employed have serious limitations that directly affect the reliability of results for fire and burnt area monitoring…[and] the regional and global effects of fire activity taking place in insular Southeast Asia are in danger of being underestimated". Likewise, in a review of monitoring landscape change associated with swidden agriculture in SEA, Li *et al.* (2014) conclude that fine-resolution imagery such as Landsat is essential for assessing fine-scale changes in landscape features.

Table 1: Extent of 'savanna' vegetation types, and fire frequency over the 14-year period 2000-2013, in major countries in the Asia assessment region.

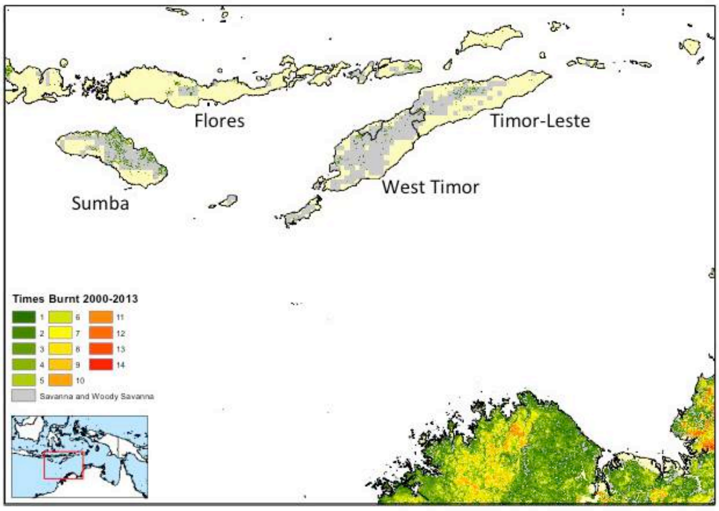
Notes:
[a] country extents determined from GIS assessment of University of Maryland land use cover product (MCD12Q1) derived from MODIS imagery, using Albers projection.
[b] 'savanna' vegetation types derived from International Geosphere-Biosphere Programme (IGBP) classification, where grassland has <10% woody cover, savanna 10-30% woody cover over herbaceous understory, woody savanna 30-60% woody cover over herbaceous under storey.
[c] mapped distribution of 'savanna' vegetation types derived from University of Maryland MODIS-based land use cover product (MCD12Q1), using Albers projection.
[d] mapped annual fire extent 2000-2014 derived from University of Maryland MODIS-based burned area product (MCD45A1), using Albers projection.

Country	Area (km^2)[a]	Proportion of country with savanna[b,c] vegetation types (%)				Fire frequency in savanna vegetation (fires yr^{-1} X 100)[d]			
		Grassland	Savanna	Woody savanna	Total	Grassland	Savanna	Woody savanna	Total
Afghanistan	520173	33.4	0	0	33.4	0.02			0.02
Australia	7689892	4.8	8.4	8.2	21.4	8.31	20.65	5.81	12.2
Bangladesh	139732	0.5	0	10.5	11	0.01		0.70	0.70
Bhutan	38663	17.3	0	0.7	17.9	0.21		0.01	0.21
Cambodia	181589	0.9	0	29.9	30.9	4.46		12.96	12.7
China	4683131	30.5	0	7.9	38.4	0.25		0.12	0.22
India	3150853	1.5	0	13.1	14.6	0.17		2.19	1.99
Indonesia	189496	0.1	0.8	0.4	1.3	0.01	1.6	1.01	1.3
Laos	230025	0.3	0.1	8.2	8.6	0.11	0.61	1.71	1.64
Myanmar	668873	0.3	0.3	26.3	26.9	0.35	2.67	6.95	6.84
Nepal	147915	23.6	0	1	24.6	1.24		0.1	1.19
Pakistan	835769	4.6	0	0.1	4.7	0.02		0.17	0.03
Papua New Guinea	456656	0	0	0.1	0.1	0.09	1.6	0.45	0.5
Philippines	297022	0	0	0.4	0.4			1.4	1.4
South Korea	39276	0	0	0.2	0.2			0	0
Taiwan	36272	0	0	0.4	0.4			0	0
Thailand	514989	0	0	14.3	14.3			1.99	1.99
Timor-Leste	14944	0	7.8	30.4	38.1		0.45	0.76	0.7
Viet Nam	328088	0.1	0	13.4	13.5	2.26		1.25	1.26

These detection issues also apply to more open-canopied situations. For example, Fisher *et al.* (2006) undertook an assessment of biomass burning in grassland and more wooded savanna areas, respectively on the eastern Indonesian islands of Sumba and Flores. Using Landsat imagery (30 m pixels), those authors observed that means of 29% and 11% of respective 7,000 km^2 Sumba and 3,000 km^2 Flores study sites were burnt, with ~90% of all mapped fires being <5 ha extent. By contrast, note the generally very low level of fire extent detected using the MODIS MCD4561 product, in Sumba, Flores and the predominantly savanna lands of Timor / Timor-Leste, over the period 2000-2013 (Fig. 28).

Figure 28 Fire frequency and 'savanna' vegetation in continental Southeast Asia assessment region. Vegetation

Vegetation mapping (IGBP classification) from University of Maryland MODIS land cover product (MCD12Q1).
Burnt area mapping from MODIS-based product (MCD4561) with 500 m pixels



The above fire detection issues also have significant implications for estimates of biomass burning emissions in the Asia assessment region (Hao & Liu, 1994; Streets *et al.,* 2003; Song *et al.,* 2010; van der Werf *et al.,* 2010). On the basis of most recent comparative data, including an attempt to take into account small fires, Randerson *et al.* (2012) estimated that, between 2001-2010, a mean of 14.4 M $ha.yr^{-1}$ was burnt (3.1% of the global area burnt) of their combined Southeast Asian (taking into account mainland SEA to India, but excluding China) and Equatorial Asian (insular SEA) regions. These fires contributed a mean 319 Tg $C.yr^{-1}$ (12.6% of global biomass burning emissions; 1 Tg = 1M tonnes). The disproportionately high level of Asian emissions relative to the area burnt is due to emissions from peatlands, especially Kalimantan—of note, however, is that the assessment period does not include the massive peatland fires, and associated trans-boundary haze issues, associated with the 1991, 1994, and 1997/98 el nino years (Page *et al.,* 2002).

Cultural fire management practices in Asian savanna settings

A substantial and growing literature addresses issues surrounding the extent, distribution, practice, livelihoods, environmental sustainability, and policy responses addressing traditional and contemporary swidden agroforestry systems in Asia, SEA especially. The journal *Human Ecology* has devoted two special editions to the subject in recent years with a major focus on SEA (Mertz *et al.,* 2009a; van Vliet *et al.,* 2013). As well as contributions in those special editions, other useful recent treatments include those by Karki (2002), Fui *et al.* (2012), van Vliet *et al.* (2012), Nigh & Diemont (2013), and Li *et al.,* (2014).

Mertz *et al.* (2009) define swidden cultivation in SEA as "*a land use system that employs a natural or improved fallow phase, which is longer than the cultivation phase of annual crops, sufficiently long to be dominated by woody vegetation, and cleared by means of fire*". While details of swidden practices vary considerably in different cultural settings, in general, before cultivation, plots are felled and cleared, the vegetation detritus is left to dry until the start of the ensuing wet season, and then fire is applied in a controlled manner to return ash and nutrients to the soil. Cultivated plots may then be used for 5 or so years, or until the plots become relatively unproductive, and the process is repeated at another site.

This definition of swidden implicitly recognises the key connection with woody systems, forests especially. Most of the associated literature thus addresses originally forested settings, and focuses on the sustainability of swidden practices in light of accelerating changes and challenges from increasing population pressure, reduced fallow periods, and shifts to more sedentary intensive agricultural practices (e.g. perennial cropping and plantations).

Traditionally, fallow periods of >10 - >20 years are considered sustainable in forested systems, including in less productive semi-arid areas (e.g. Mertz *et al.,* 2009a; Fui *et al*., 2012; FAO, 2015; Mello, 2015). Today, however, fallow periods have become as short as 3 years in various situations, with ensuing impacts on declining soil fertility (Erni, 2009; Fui *et al.,* 2012; Mello, 2015). Contrary to much popular and official belief, well managed swidden systems can confer significant soil, nutrient and water conservation benefits relative to more intensive land use systems (Bruun *et al.,* 2009; Erni *et al.,* 2009; Fox *et al.,* 2009; Fui *et al.,* 2012; Nigh & Diemont, 2013; Mello, 2015).

Given the evident inverse relationship between long fallow recovery periods with population density pressures, as a rule of thumb van Noordwijk *et al.* (1995) suggest that, as a simple guideline, in the humid tropics a population density of 10 people per km^2 may be a sustainability threshold. Mertz *et al.* (2009b) suggest that as many as 30 million people in Southeast Asia were engaged in swidden agriculture at the time of their assessment. However, recent evidence suggests that numbers of strictly swidden cultivators are declining both globally and in SEA, with those participating in more sedentary and commercial forms of agriculture substantially on the increase (Padoch *et al.,* 2012; van Vliet *et al.,* 2012; Mertz *et al.,* 2013; Li *et al.,* 2014). Stott (1990) provides a detailed description of demographic and socio-political processes (including war activities) contributing to rapid agricultural clearing, deforestation, and fragmentation of the Korat Plateau, northern Thailand.

Relatively little information is available for land use practices in more open, less woody (derived or natural) savanna environments in the Asian region. However, under such conditions pastoral activities and associated burning practices appear to assume greater prominence in the mix of livelihood options (Stott, 1990; Ataupah, 2000; Maxwell, 2004; Russell-Smith *et al.,* 2007; Schmerbeck & Fiener, 2013). On Timor and adjacent islands where savanna-based livelihoods are widely practised, Ataupah (2000) neatly describes current land use as constituting essentially an agro-silvipastoral system.

However, as with changing swidden practices in more forested situations, the same drivers affecting the sustainability of traditional savanna livelihoods are at play (Stott, 1990; McWilliam 2000; Schmerbeck & Fiener 2013). While initial drivers may appear to involve increasing population pressure and development of more settled forms of agriculture, equally significant are: (1) the breakdown in traditional management systems, including cultural regulation over the usage and resources and management of fire (Ataupah 2000; McWilliam 2000; Russell-Smith *et al.,* 2007); and (2) tenure disenfranchisement and broader political agendas imposed on traditional farming practitioners by states and their agencies, especially commercial forestry and agricultural interests (Fox *et al.,* 1999, 2009; McWilliam 2000; Karki, 2002; Tacconi & Ruchiat, 2006; Russell-Smith *et al.,* 2007; Erni, 2009; Fui *et al.,* 2012).

Regulatory frameworks and their impacts on savanna fire management

After the major transboundary haze issues of 1997/98, ASEAN ratified a zero-burning policy in 1999. While there has been some recognition that fire management plays a key role in the livelihoods of many regional people (including swidden agriculturists), and that guidelines for small landholders and farmers are apparently under development, the official no burning policy is recognised to have abjectly failed to deliver improved environmental and social outcomes (FAO, 2007; Fui *et al.,* 2012).

In turn, that policy failure can be attributed to a long history of lack of understanding of the practical livelihood and environmental benefits that effective swidden systems can deliver (Karki, 2002; Bruun *et al.,* 2009; Erni, 2009; Fox *et al.,* 2009; van Vliet *et al.,* 2012, 2013), and denial of major causes of regional fire management problems attributable to deforestation and degradation associated with poor forestry and agricultural management practices

(Tacconi, 2003; Harris, 2012; Gaveau *et al.,* 2014). Fui *et al.,* (2012: 373) summarise the situation thus: "the overall impact of Western colonialism, development of modern states and the adoption of scientific forestry emphasizing timber production for international markets, and agriculture development, has been the reduction in the forest areas in Southeast Asian countries. Infrastructure development, improved communication and transportation networks, and intrusion of external markets have transformed and marginalized the traditional forest communities, resulting in denial of their customary rights, as well as erosion and loss of traditional knowledge, practices, and institutions".

A further consequence of the erosion of customary rights is the legacy impact this may have for local communities to engage with the undertaking of GHG emissions mitigation and offset projects. Such issues include state recognition of communal title arrangements, the legal rights of local communities to undertake projects which involve fire management, and dealing with complex multi-level governance involving local, regional, national and international systems and requirements (Karki, 2002; Russell-Smith *et al.,* 2013). Niall *et al.,* (2013) describe these issues in detail in a SEA context, particularly with reference to emerging opportunities for regional REDD+ projects.

Potential applicability of methodology-based savanna fire management in promising sub-regions

A first issue is the extent to which the methodological requirements underpinning savanna burning projects developed for the extensive, sparsely populated savannas of northern Australia can meet the fire management and development needs of densely populated, fragmented savannas of the Asian region, SEA particularly. Despite self-evident contextual differences, and a raft of associated technical and policy challenges, at the core of sustainable livelihoods and environmental management there is a common prerogative to apply prescribed strategic fire management from the early-mid dry season period to restrict the spread of late dry season wildfire. Building on well-documented traditional SEA swidden practices, applying such methods will reduce fire emissions, enhance biomass and soil carbon conservation, and provide a range of tangible rural livelihood and ecosystem services benefits.

Major differences between benefits derived in Australian and SEA savanna settings therefore entail (1) vast spatial opportunities for generating carbon benefits under Australian conditions, with (2) spatially restricted, but very substantial livelihood and environmental benefits in densely populated rural SEA settings. The latter carbon credit benefits, while relatively small in quanta, need to be considered more broadly within local community contexts—for example, as part of developing integrated land management and livelihoods approaches at catchment scales (Djoeroemana *et al*., 2007; Anda, 2013). Anda

(2013) provides an excellent example of such an approach integrating carbon with other land management options in the Laclo catchment, Timor-Leste.

As outlined above, identifying appropriate fire-prone savanna Asian sub-regions for potential savanna burning projects presents considerable challenges given the dearth of reliable vegetation and associated fire mapping data at appropriate scales, and paucity of cultural / ethnographic information concerning fire management practices in traditional and contemporary regional savanna settings. The available SEA literature concerning cultural landscape fire management issues and problems is almost exclusively focused on swidden agriculture in forested (and derived forested) settings.

A case in point is the assessment of wildfire issues in Myanmar currently being undertaken for the purposes of developing a GEF (Global Environment Facility) national fire management initiative (FAO, 2015). That document notes that most wildfire activity currently occurs in forested upland settings, apparently especially in association with teak plantation preparation. The fire activity metrics used in that FAO (2015) assessment are derived from the same (patently inadequate) MODIS fire mapping data as reported here (Table 1). In combination with savanna vegetation mapping derived from MODIS land cover mapping (MCD12Q1), the overlay of MODIS-derived fire mapping for the period 2000-2013 purports to show that savanna vegetation types are seldom burnt in Myanmar (Fig. 27). The real situation is unknown.

Based on these same MODIS-derived savanna vegetation and fire mapping products, parts of Cambodia would appear to provide the best potential (i.e. largest geographic extent of fire-prone savanna) for savanna burning projects (Table 1, Asia Fig. 27). However, as for SEA generally, such relevant information as exists for Cambodia addresses mostly forest swidden systems (e.g. Fox, 2000; Maxwell, 2004; Mertz *et al.,* 2009b; Schmidt-Vogt *et al.,* 2009), and only one geographically restricted published study (Maxwell, 2004, and references therein) describes cultural burning practices in savanna (referred to mostly as comprising Dry Dipterocarp Forest) vegetation.

Maxwell (2004) describes the savanna fire management process as: "The burning occurs from January through March (mid-late dry season), and triggers regrowth of fresh grass for use in house construction and probably as forage. Fires are set usually to open up the ground for travel and hunting. As the environment is so dry, fires get of control easily, and many of the fires are accidental results of smoking, cooking, resin extraction from dipterocarps, or efforts to smoke out bees, pangolins or monitor lizards from hollow logs. The people interviewed said there are no natural fires, i.e. people set the fires. The villagers did not say that providing fresh grass for cattle forage is a motivation for burning…but regrowth obviously is important for supporting both wild and domestic cattle in the late dry season." The geographic extent of such practice is not described.

At the present time, therefore, there is insufficient reliable information to draw many useful conclusions about the location or prioritization of potential savanna burning projects generally in continental SEA. Nevertheless, considerable contextual ethnographic (e.g. Ataupah, 2000; McWilliam, 2000; Therik, 2000; Russell-Smith *et al.,* 2007) and some technical (e.g. Russell-Smith *et al.,* 2000; Fisher *et al.,* 2006; Djoeroemana *et al.,* 2007; Lasco & Cardinoza, 2007) data are available, for fire-prone savanna landscapes of the semi-arid eastern Indonesian Archipelago (especially NTT), and contiguous Timor-Leste.

Semi-arid eastern Indonesian Archipelago and contiguous Timor-Leste.

Fire management issues affect the rural livelihoods of over 4 million people in the Indonesian Province of Nusa Tenggara Timur (NTT) and the adjoining Democratic Republic of Timor-Leste (TL).

The savannas of Timor-Leste (TL) and the contiguous eastern Indonesian Province of Nusa Tenggara Timur (NTT) share many livelihood development challenges. As much as 80% of the population is reliant on subsistence agriculture. Food insecurity, malnutrition, and grinding poverty are endemic in rural areas—exacerbated by typically rugged and infertile landscapes, precarious seasonal water availability, and limited built and social infrastructure resources. These conditions are well recognised and documented, and the focus of substantial development assistance.

Destructive fire regimes often impacting agriculture and human infrastructure, represent a major livelihoods issue in this sub-region. Successive internationally and regionally funded scientific collaborations and projects have identified it as a major concern (Russell-Smith *et al.,* 2007; UNU 2015). Since 1995, a number of major regional initiatives have been undertaken to attempt to address fire management challenges in that combined region.

Most recently, at a sub-regional workshop convened by the UNU and with the support of the Australian Government in Kupang Indonesia, international and local academic experts, government officials and local NGOs and community leaders came together to elaborate the fire challenges facing the region (UNU, 2015). Many of the observations offered in that workshop correspond to those outlined in a 2007 study of rural livelihoods and burning practices in the province of Nusa Tengarra Timur, including the islands of Flores and Sumba (Russell Smith *et al.,* 2007).

As reported in the proceedings of the UNU workshop, particular contextual factors identified as leading to current destructive fire regimes include the breakdown of traditional power structures, combined with the limited economic opportunities, food insecurity and lack of farm production. This then leads to people using fire in a range of ways, such as for hunting and agricultural clearing that are now less regulated in magnitude and seasonality than they were under traditional leadership systems. In addition, the use of fire is generally prohibited in law. The direct costs of such fire regimes include damage to infrastructure, catchment erosion leading to sedimentation of irrigation infrastructure and rivers, as well as soil degradation. Indirect costs include further negative impacts on agricultural production including animal fodder, and poor food and water security. Improved fire management would be expected to enhance biodiversity protection, reduce emissions and assist in efforts to prevent savanna woodland degradation, improve agricultural production, weed management and pasture and livestock quality, improve food security, improve health indicators, reduce human conflict, promote infrastructure security, assist in climate change adaptation and disaster resilience (UNU, 2015).

The 2007 study described many of these issues in depth, as they played out in Nusa Tengarra Timor, namely at study sites in Sumba and Flores. In this sub-region, village communities occupying predominantly savanna landscapes are reliant on a range of mixed farming activities, with the emphases of the different respective activities varying across in locations.

Fire was used as an essential agricultural management tool in all study villages, again with both similarities and differences among the study sites as to the purpose and timing of burning activities. Fire was found to be used:

- restrictively - to clear and prepare old and new garden plots in readiness for planting in the forthcoming wet season;
- extensively - as part of broader-scale hunting activities, such as hunting for wild pigs and rusa deer;
- for savanna pasture management purposes, not least to encourage grass regrowth for livestock; and
- fires were also sometimes started accidentally or maliciously.

In terms of seasonality, restrictive burning for garden preparation was found to occur earlier in the year at some sites, such that these burning activities were completed by end of August. Preparatory burning at another site anticipated the new wet season rains. With some variation across sites, extensive burning for pasture management purposes was observed to occur similarly in the latter half of the dry season. Burning for hunting purposes occurred over a substantially longer dry season period at certain sites.

Burning at some sites was also taken across the year for purposes including control of locust infestations. In the months leading up to start of the wet season, burning would also assist in the harvesting of edible forest yams.

The study observed that according to community testimony, former strict restrictive fire management practices were frequently not observed. This reflected the view that, while extensive and intensive burning had always been practised, much burning at that time occurred in an unstructured fashion with attendant significant economic impacts (Russell Smith *et al.,* 2007). As also observed for the broader sub-region by experts attending the UNU workshop in 2015, underlying drivers of such behaviour were multiple and complex (Russell-Smith *et al.,* 2007; UNU, 2015).

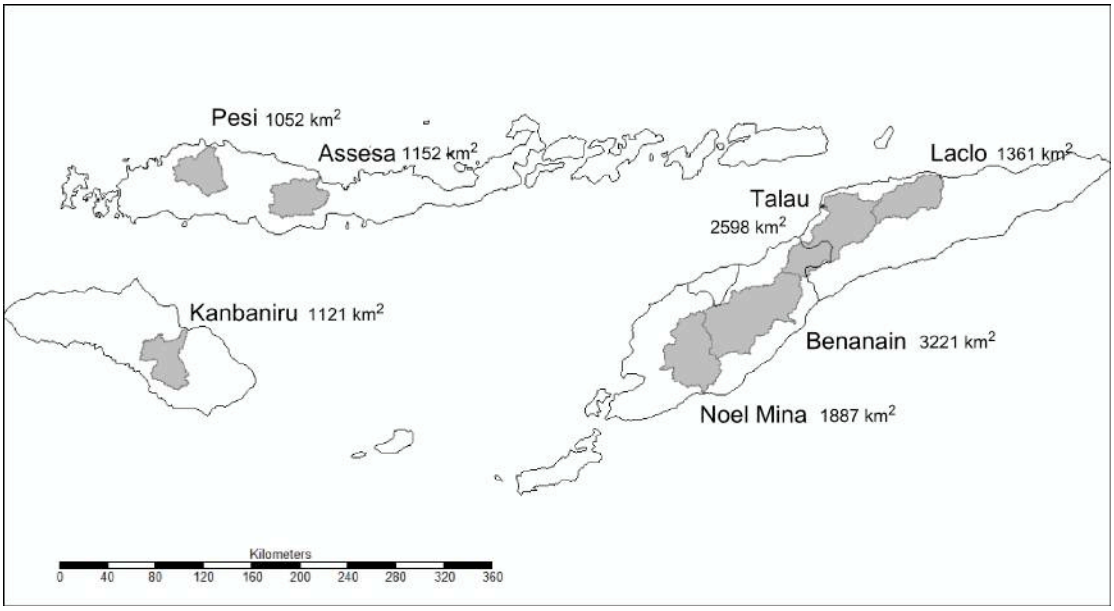
The study further illustrates, with examples of the serious implications for rural livelihoods by providing examples of how fire patterns fit in the context of community life:

> *"Over the 3 year study period numerous examples were observed by project staff where uncontrolled landscape fires destroyed buildings, crops, and inflicted needless damage on forest resources—e.g., killing mature trees on forest margins, and thereby further promoting incursions of flammable grasses and weeds (e.g., Chromalaena odorata). In 2002, most of the kebun at Dhereisa (Flores) were burnt from an uncontrolled hunting fire and, were it not for the enterprise of women through their weaving, significant hardship, including starvation, would have ensued.*
>
> *The lack of fire management planning and coordination evidenced at all study villages is all the more surprising given the very tangible benefits including economically which would accrue, if this were undertaken. For example, if, instead of burning all hillsides around kampung and kebun areas, some steep slopes were left unburnt (leaving more accessible slopes for grazing) to promote regeneration of stocks of hardy woody plants (still existing, albeit as fire suppressed suckers among the grasses), then communities would have easy access to firewood; a sore point for women in some kampung who frequently have to travel long distances to obtain supplies. Indeed, a significant component of project activities has been to undertake integrated agro-forestry and associated fire management activities in all four villages to demonstrate such practical benefits."*

The study concludes by noting that the broader social and political factors, alongside the propensity of regional savanna landscapes to increasingly carry fire as the dry season progresses, *"conspire to significantly impact on environmental assets, livelihood resources, and thereby economic conditions. Given these factors, without effective fire management and a supportive policy environment, sustainable livelihoods development will continue to be elusive in savanna landscapes of eastern Indonesia"(*Russell Smith *et al.,* 2007).

Particular catchment areas identified by the UNU workshop participants and regional experts as possible sites for incorporating fire management and mitigation activities within broader integrated catchment management development projects at the sub-regional level included those key catchments identified in Asia Figure 29 below.

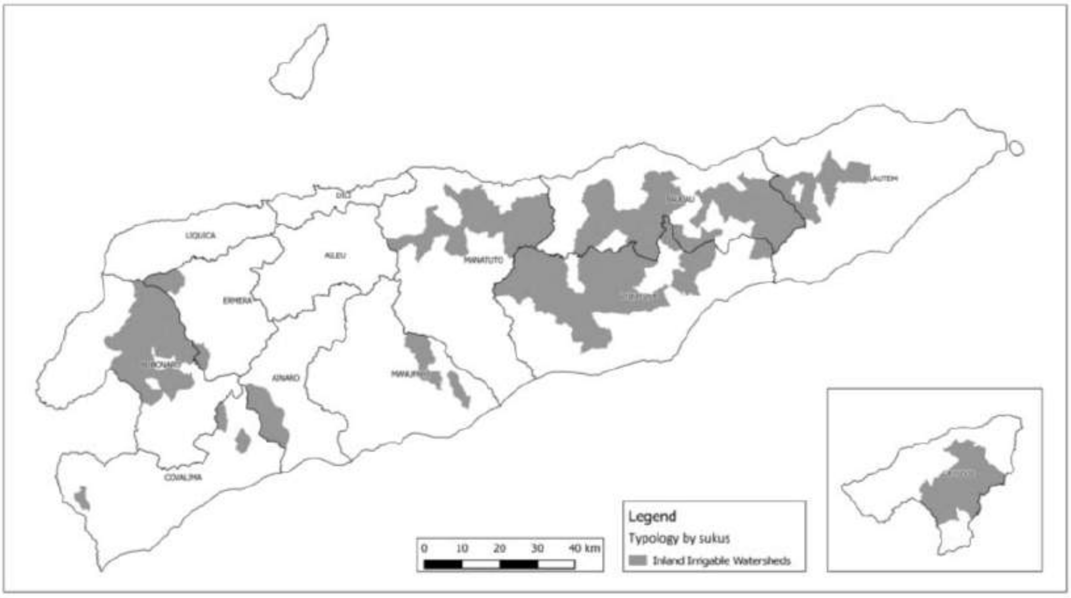
Figure 29 Major catchment areas in NTT and TL mentioned at International Savanna Fire Management Initiative Kupang workshop (May 2015) as possible sites for incorporating fire management and mitigation activities within broader integrated catchment management development projects (Source: Rohan Fisher, CDU).



A significant, if generally little appreciated issue not addressed in most regional livelihood development programmes concerns the critical role of fire—both as an essential component of traditional agricultural, agroforestry and pastoral management practice and, given breakdown of traditional management systems associated particularly with burgeoning population and land-use pressures, a key contemporary threat to those same livelihood, soil, water, and down-stream irrigation resources. Based on extensive experience (see below), a considered assessment of major rural livelihood / development initiatives currently being undertaken or planned for in TL-NTT indicates that failure to address such core fire practice issues poses critical risks to their successful implementation.

For example, Asia Fig. 30 below illustrates inland watershed project areas identified for an upcoming aid project. In this region, problematic fire regimes threaten to undermine project goals.

Fig. 30 Timor Leste Inland watershed project areas identified for DFAT's impending TOMAK project (TOMAK—To'os Ba Moris Diak: Farming for Prosperity, Investment Design Document. DFAT early release version, August 2015)



A concept proposal addressing *Savanna fire management, rural livelihoods and sustainable development in eastern Indonesia and Timor-Leste,* is available separately. In contrast to the current Australian *savanna burning* model that focuses solely on the generation of carbon credits through GHG emissions abatement and carbon sequestration, the eastern Indonesia -TL proposal essentially aims to integrate abatement and sequestration benefits within a broader, catchment-based, rural livelihoods development framework. While the proposal specifically relates to the institutional circumstances of NTT and TL, the framework has generic application to densely populated, highly fragmented fire-prone savanna settings characteristic of SEA, and possibly even more broadly in the Asian region.

The concept proposal had its recent genesis at a workshop, held in Kupang NTT, Indonesia) in May 2015, under the International Savanna Fire Management Initiative. The workshop explored options for implementing similar market-based savanna burning mitigation activities in Asia, with a particular focus on Australia's near region. Workshop delegates affirmed strong support for a transnational collaboration involving Indonesian (especially NTT), TL, and Australian core partners.

Subsequently, follow-up discussions were held with key NTT, TL and Australian partners, including in Dili (TL), to flesh out a concept proposal. The initiative has strong regional institutional support and provides a solid and useful platform for on-going regional fire management collaboration.

Assuming that there was strong NTT – TL community, government agency, and NGO support for developing pilot projects based on integrated catchment management precepts as described above, a long term approach that shared information across the region would be necessary to address the technical challenges associated with pilot site projects. These challenges include:

- long-term engagement with catchment communities and administrative authorities, particularly with respect to developing land use planning including;

a. implementing strategic fire management approaches for extensive grassland/savanna areas (e.g. Russell-Smith *et al.,* 2007);

b. enhanced agricultural / swidden management, including application of alternative non-burning management approaches (e.g. use of bio char: Mello, 2015);

c. establishing/maintaining agro-forestry and stream-bank stabilization initiatives, including application of strategic fire management (Pearson & Templeton, 2009);

- development of fine-scale (at least 1:50,000) land cover maps reliably describing the distribution of vegetation cover (forest, savanna, etc.), land use (pastoral, agricultural, agro-forestry—including swidden), water and soil resources. Some such data is available both for NTT and TL but, even where available, would require validation (e.g. Fisher, 2010);

- development of fine-scale (e.g. Landsat) fire mapping. Fire mapping at Landsat scale has been found to be reliable, even given that the great majority of savanna fires are <5ha (Fisher *et al.,* 2006). A study in progress has provided 20+ years of fire mapping derived from Landsat for the Benanain catchment, NTT (Kristianus Berek, pers. comm.);

- development of fire emissions abatement, and carbon sequestration, inventories, including the quantification of emissions in different vegetation from fires of different intensities, and based on above mapping frameworks, substantial experience in Australia (e.g. Russell-Smith *et al.,* 2009; Murphy *et al.,* 2015), and some relevant research already undertaken in TL (Lasco and Cardinoza, 2007) utilizing procedures as set out in manuals produced by the World Agroforestry Centre and IPCC (Inter-Governmental Panel on Climate Change) good practice guidance for LULUCF (Land Use and Land Use Change and Forestry); and

- development of robust and equitable governance, and associated market / payment for environmental services, arrangements.

While these are substantial challenges they are achievable with appropriate foundational and preparatory work in collaboration with government and communities.

Applying SFiM in this sub-region represents an important and valuable opportunity to support sustainable livelihoods and safeguard public infrastructure and investment in the region. While the densely populated, smaller tracts of savanna will require a different approach to that used in the Australian context, the benefits for local people and the environment are likely to be no less significant, and perhaps more so, given the number of people's lives in such a highly populated sub-region who could be directly and positively impacted.

Apart from these stand-alone benefits for the sub-region it would be expected that improved SFiM in this sub-region, together with improved datasets and spatial imagery, would provide a foundation for the transfer of experience and expertise across the region as a whole. Such as a transfer of experience and expertise would then pave the way for improved SFiM in the Asia region as a whole.

PART X – FUTURE PROSPECTS

Introduction

Finding potential investors and understanding the interests of purchasers of the outputs of fire management abatement projects, or the demand for carbon credits, offsets and ecosystem services, is an important aspect of undertaking a SFiM project. Consequently, the Initiative has continually monitored and analysed demand for these outputs, with a particular attention to demand of the carbon market. This analysis has also extended to exploring the full range of SFiM options and mechanisms not reliant on participation on carbon markets, including through payment for ecosystem services, public and philanthropic funding sources.

Finding information about demand for these products is difficult and challenging for several reasons. The experience and goals of SFiM projects and purchasers of SFiM credits is very context specific and different for each and every project. Compounding this is the lack of transparency in the market. Many transactions are commercially confidential, further hampering informative detailed analysis. The dynamic nature of the policy environment that the projects are working in, with significant changes being made at the local, national and international policy levels, with more to come in the foreseeable future causes further challenges.

Another factor that complicates analysis of demand is that all of the SFiM projects use multiple sources of support and finance to produce their SFiM credits. The demand for carbon is therefore not the whole picture or in some cases even the main driver for the project. Certainly for many of the Indigenous peoples' groups that were consulted as part of the Initiative carbon is not an important motivation. Nevertheless, the carbon market provides a new opportunity for many Indigenous peoples to participate in a commercial market, which is potentially a significant and, more importantly stable, non-government source of income for these communities. Mainstream development assistance in the form of welfare payments, foreign aid and philanthropy although very important are more uncertain and less sustainable. For this reason this analysis of demand focuses on demand of the various carbon markets and will only touch on these other more main stream channels of support for SFiM projects.

Experience in Australia for SFiM credits

WALFA, the first SFiM and credits project, was in effect an example of a voluntary or offset credit. ConocoPhillips were required to deliver an offset for the impact caused to Darwin Harbour by their Liquified Natural Gas (LNG) terminal. Through Charles Darwin University they and the Northern Territory Government were aware of the possibility of delivering a biodiversity offset through improved fire management in West Arnhem Land. They agreed with the Northern Territory Government to provide the traditional owners of the project area $1m per year for 17 years for undertaking traditional fire management (TFM), and in return they were granted permission to build their LNG terminal in Darwin Harbour and receive 100,000 tonnes of carbon credits per year, representing the carbon abatement achieved by the traditional owners. In 2007, at the start of the project, the price was A$10 per tCO2e. This original price has been indexed to inflation so that in 2015 the project is now receiving more than A$14 tCO2e. Despite significant changes in the global and Australian carbon market since 2006, both ConocoPhillips and the Traditional Owners remain fully committed to the original agreement and price structure. Another important value for the indigenous community has been the stability and longevity of the agreement, which in a very real way has amplified the value of the actual price of the carbon. The Traditional Owners have been producing around 145,000 tonnes per annum and have been selling the excess credits into the Australian carbon market.

The next SFiM credits came from the Fish River project. In this project, the traditional owners, ILC and TNC worked to meet the requirements of the relevant carbon market in Australia. The project was approved by the Government (the Clean Energy Regulator) in October 2012 and their SFiM credits were sold to Caltex. Although the price is confidential, the project reported that it sold 25,884 compliance credits (ACCUs) to Caltex for over $500,000, around A$22/tCO2e, or A$1.50 per hectare per year. The compliance value of ACCUs at the time was A$23/tCO2e (Australian Broadcasting Corporation, 2013).

Following on from the Fish River project, numerous other SFiM credits were generated. For example, KLC sold 280,000 ACCUs to Qantas. At the end of December 2014, there were 38 registered projects generating 1.4m ACCUs. 14 were traditional owners representing some 80% of the credits. Further details of these projects are available at: http://tfm.unu.edu/toolkit/australia/indigenous-savanna-fire-management-projects.

Pricing for each of these projects are covered by commercial confidentiality clauses and therefore not publically known. Nevertheless, media reports have stated that the projects that followed the Fish River project have received less, due to uncertainty at that time about the market in Australia, and an increase in the supply of SFiM credits,.

Under the Australian Government Emission Reduction Fund (ERF), providers of eligible credits, including SFiM credits, are able to bid into a closed reverse auction process.

As of December 2015 there have been two auctions. The first auction was held on 15-16 April 2015. The Government purchased 47 million carbon credits for an average price of

A$13.95 tCO2e. 14 SFiM projects registered for the auction process. Two SFiM projects were successful. The next auction was held from 4-5 November 2015. There are 54 registered SFiM projects with the ERF scheme. The Government purchased over 45 million tonnes of abatement at an average price of $12.25 per tonne. This second auction has firmly established the market for SFiM credits and will provide a solid basis for these projects for the foreseeable future.

As a result of these two auctions there are now a total of 36 contracts with SFiM projects for a total of 7,070,000 tonnes of ACCUs. 12 of these SFiM projects are Indigenous-led, for a total 3,513,000 tonnes of ACCUs. These are:

Project	Tonnes of CO2	Period (years)
The Olkola Ajin – Olkola Fire Project	455,000	7
The Raak Nguunge Project	30,000	7
Jawoyn Fire Project	18,000	6
Fish River Fire Project	115,000	5
Batavia Fire Project	245,000	10
Merepah Fire Project	95,000	10
WALFA	500,000	10
WALFA II	1,284,000	10
South East Arnhem Land	230,000	10
Olkola Ajin II	455,000	5
Oriners & Sefton	36,000	4
Savanna Burning Investment Readiness Programme Cape York	60,000	5

There are a further 24 SFiM projects with non-indigenous organisations, mainly large pastoralists, for a total 4,032,141 tonnes of ACCUs. Details about these projects and their contracts are available from the Clean Energy Regulator and the Initiative's toolkit[1].

Aggregation of projects is allowed under the ERF and welcomed by the Government. Country Carbon and Corporate Carbon Solutions are two companies that are aggregating SFiM projects in Australia. Country Carbon has contracts with the Government for 19 of the 24 SFiM non-indigenous-led projects. Corporate Carbon Solutions has contracts with the Government for Fish River and Merepah SFiM projects. These aggregators are also discussing with other SFiM projects, about the possibility of purchasing the entire amount of credits they can generate from year to year, rather than just the credits they are willing to promise to deliver over a fixed period of time. This is more due to natural variability of fire burning and thus bringing down their own costs per actual tonne produced. Others are considering proposals where the ERF partly funds the project and additional funds are sourced through payment for ecosystem services (PES) schemes or voluntary market or

[1] see www.cleanenergyregulator.gov.au; http://tfm.unu.edu/toolkit/australia/indigenous-savanna-fire-management-projects

future sales. Most expect the market to become more sophisticated and with it more options for SFiM that aren't entirely dependent on ERF contracts.

A widespread challenge for all the SFiM projects that has a significant impact on pricing and in turn demand is the lack of reliable market information about projects. The Clean Energy Regulator publishes the weighted average price paid for ERF contracts across successful bids following each auction to provide information to future participants about auction prices and support the development of projects. The pricing, however, for individual ERF contracts for is confidential as is the case for most of the other contracts. This contributes to the challenges if indigenous groups not normally have the same capacity and knowledge to negotiate than compared with buyers of SFiM credits.

Despite the obvious benefits of SFiM project collaborating, especially with respects to promoting demand, this only happens informally. This asymmetry in capacity and market intelligence has lead to most of the key indigenous organisations working on SFiM projects to call for great coordination and collaboration.

Australian Voluntary Markets Potential Demand for SFiM credits

Voluntary markets have represented an important source of demand for SFiM credits. The first SFiM project, WALFA, was in a sense financed by voluntarily selling carbon credits to ConocoPhillips.

INPEX in June 2011, in very similar circumstances to the WALFA/ConocoPhillips project and as part of it's agreement with the Government of Australia, The Northern Territory Government and Total to develop the Ichthys LNG Project, promised to invest A$37m in savanna burning. Details of how this will be used have yet to be announced.

Qantas has supported the north Kimberley savanna burning programme under its voluntary carbon abatement scheme and says it will continue to support these projects regardless of any new rules for government-funded carbon credits. Qantas has indicated that it is interested in discussing with the KLC and other Native Title groups options for supporting SFiM projects by purchasing the co-benefits of a project such as biodiversity and health outcomes, and supporting the relevant group to sell the carbon benefits through the ERF process, though it is not yet clear whether these outcomes will be realised.

Caltex bought the SFiM credits from the Fish River project.

ConocoPhillips is considering developing its involvement with SFIM projects both within Australia and in countries where it has sites. At the most recent South East Asia Australia Offshore & Onshore Conference in August 2015 they showcased the WALFA project.

Resource companies have also shown interest in SFiM projects due to the potential links to their social goals, especially in regions where they have operations. BHP Billiton, for example, has an asset in Cerrejon, Columbia and in this region there is some evidence of the local and indigenous people (Wayuu and Guajiros) having practised TFM in the arid plains and Sinu Valley Dry Forests of the region. ConocoPhillips have an asset in the Middle Magdalena Basin, Colombia, and in this region there is some evidence of the local and indigenous people (Mitilones (Bari) and Chimilas) having practised TFM in the Magdalena Valley Montane Forests and Northern Andean Paramo where fire is one of the main threats of the Northern Andean Paramo. INPEX has an asset in Cuervito and Fronterizo blocks, Mexico, part of the Burgos Basin part of Sierra Madre Oriental and there is some evidence of the local and indigenous people (originally Chichimec and Huastec, now Coahuiltecans) having practised TFM in the Tamaulipan Matorral - desert shrubland made up of woody shrubs, small trees, cacti and succulents.

More broadly, Australia has a voluntary market of 1-2m tonnes per year. The main buyers are Qantas and Virgin (Australia's two largest airlines), banks and other financial institutions that voluntarily offset their emissions (such as travel and electricity) or have a programme that allows their customers to do so. This is part of the Australian Government's National Carbon Offset Standard and associated Carbon Neutral programme. Prices for offsets units that are purchased are understood to vary amongst companies and the project types they choose, but prices within the A$8 to A$12 range are understood to have been paid by some carbon neutral companies.

No Australian SFiM project has so far accessed international voluntary markets. Some opportunities have been explored. For example, Virgin Unite, the entrepreneurial foundation of the Virgin Group, visited Northern Australia in 2011 to consider investing in SFiM projects.

Philanthropic organisations have also considered ways to help traditional owners access carbon markets for SFiM projects. Although most of these projects have focused on traditional forms of philanthropy, such as capacity development and scientific research, some have and are considering more market-orientated forms of support such as purchasing SFiM credits. For example, the Yajilarra Trust is considering investing in SFiM credits in Australia.

Australian SFiM use of Ecosystem Services

Australian SFiM Projects have significant co-benefits that have attracted payment, such as landcare, invasive pest control, biodiversity management, tourism, water management, border protection, customs and quarantine services. Consequently, these other schemes have been very influential in developing SFiM projects and bringing SFiM credits to market. WALFA, for example, was initially funded by the Australian Government Community Development Employment Projects (CDEP) scheme, but receives income from many other sources. Most of the other SFiM Projects in Australia have similar backgrounds and relationships. The Australian Government though their Working on Country programme committed in 2013, over A$320 million over five years to support 730 Indigenous rangers that have provided the core staff for most of the SFiM projects. The Government also invests more than A$1 billion per annum through the National Landcare Programme, including more than A$450 million directed in regional funding through to Australia's 56 natural resource management organisations to enable communities to take practical action to improve the environment, many of which are directly related to the work for SFiM projects.

The importance of this additional support for SFiM projects in Australia is hard to overstate, providing most SFiM projects with crucial start up and development funds and making SFiM project financial sustainable and viable. The wide spread success of indigenous-led SFiM projects in the ERF is, significantly, due to various Government and philanthropic pilot schemes that provided critical training, support and funding to help Traditional Owners and support the undertaking of the necessary preparatory work to develop a viable proposal. One example of this is the Christensen Fund which also provided important seed funding for many of the SFiM indigenous projects.

This relationship means accurately quantifying the cost of producing an SFiM credit in Australia is difficult and many SFiM Projects are not entirely dependent for the viability on the income they receive from their carbon credits.

Regional and National Carbon Markets Demands for SFiM Credits

Carbon markets around the world ultimately drive demand and price, both directly as consumer of credits and indirectly through the influence they have on voluntary markets.

Carbon markets have been implemented or are scheduled to commence in 39 national and 23 subnational jurisdictions covering 23% of global emissions or 7 GtCO2e (World Bank, 2015). The value of the carbon markets globally in 2015 is estimated to be just under $50 billion, compared to 844 MtCO2e in emissions reductions worth $4 billion in the voluntary markets (World Bank, 2015).

Prices observed vary widely and reflect the national or regional context of the instrument in question – from less than US$1 per tCO2e to US$130 per tCO2e. The majority of emissions (85%) are priced at less than US$10 per tCO2e (World Bank, 2015).

The Intended Nationally Determined Contributions (INDCs) refers to the formal submission made by Parties to the UNFCCC about their post 2020 climate change plans. INDCs give some insights into countries' plans and climate change policies. Some INDCs also shed light on the potential use of carbon markets toward meeting post-2020 emission reduction targets.

Many countries have indicated that they may use international carbon markets to meet their targets. This includes Japan, New Zealand, Norway, South Africa, South Korea and Switzerland. A number of countries have also left open the option of using international carbon markets to meet their targets, while some countries have indicated that they would not be using international markets.

REDD+ as a Source of Demand for SFiM credits

Although SFiM projects are not REDD+ projects, the demand and pricing for REDD+ projects is a valuable reference of the potential market of savanna fire projects. Also some REDD+ projects have implemented SFiM techniques that are in the process of developing fire abatement methods. The most developed of these is Mpingo Conservation & Development Initiative (MCDI) in the Kilwa District, Tanzania. Although primarily a REDD+ Project, the foremost driver of forest degradation in MCDI's project is annual burning of miombo woodlands, which suppresses tree growth and biomass. The project therefore invested in developing a new methodology for carbon accounting in miombo woodlands affected by fire, a method that could be applied widely within the miombo biome that covers some areas southern Africa. The avoided conversion of grasslands in the Taita Hills of Kenya is another example of where the REDD market has provided credits for what could also be considered an SFiM project. Here the inclusion of grasslands in REDD+ makes sense given their potentially high carbon storage as well as the fact that savannas are interspersed with forests on the ground and face the same threats of conversion. Both project demonstrate how SFiM projects can be adjusted to meet REDD+ requirements.

Aid programmes, in addition to the $3.29 billion pledged by multilateral and bilateral agencies to developing countries for developing REDD+ preparedness and REDD actions, have also committed to purchasing REDD+ credits. These currently comprise the:

- BioCarbon Fund Initiative for Sustainable Forest Landscapes (ISFL),
- the KfW (German Development Bank; Kreditanstalt für Wiederaufbau) REDD+ Early Movers Programme; and,
- the Forest Carbon Partnership Facility (FCPF) Readiness and Carbon Fund.

The FCPF Carbon Fund is set up to pay for emission reductions delivered by a few (indicatively six) large Programmes at a jurisdictional (e.g., provincial) or national scale. For illustration purposes, the Fund has a hypothetical price of US$5–10/tCO2e and could cover about 2% of current emissions from deforestation, i.e. 60 MtCO2e of total annual emissions of 3,000 MtCO2e. The ISFL has funding of US$309 million and will create a portfolio of about 4–6 jurisdictional Programmes. It has also planned on pricing of US$5–10/tCO2e. The KfW Early Movers Programme has US$43 million for purchasing carbon credits which is it currently doing at US$5/tCO2e.

The REDD+ market has seen a very large spread of prices across project types and offset certifications. For example, in the second quarter of 2014, ten transactions were closed through the Carbon Trade Exchange (CTX) with an average price of US$5. The average value of the credits sold encouragingly hints at a secondary market for Verified Carbon Standard (VCS) REDD+ credits that would at least meet the minimum opportunity and management costs of current forestry based projects. Price continues to be a factor in buyer preferences, although REDD+ project location and co-benefits, as well as the volume contracted, also play roles in motivating buyers. Forestry and land-use offsets were the most popular offset category in 2013 and comprised 49% of VCM value (GCP, IPAM, FFI and UNEP FI 2014). Buyers have always sought out forest carbon offsets because of their "charisma" – projects that save endangered ecosystems are easy to convey to consumers – and until recently, forestry offsets were priced significantly higher than renewable energy and have therefore sold in smaller volumes (GCP, IPAM, FFI and UNEP FI, 2014). Bids also tend to be higher on projects with maximum generating capacity below 100,000 tonnes per year. This reflects buyers' interest in smaller projects, and unwillingness to be associated with large projects as they are often seen as more risky in terms of monitoring impacts. Most of these buyers are end-users who more often than not purchase small volumes and consider small projects to have stronger environmental and social benefits than larger ones. Conversely, large-scale REDD+ projects are more attractive to project aggregators, which plan to resell purchased volumes in the future in a regulated market when, and if, REDD+ credits become compliance units (GCP, IPAM, FFI and UNEP FI, 2014).

Potential Demand for SFiM from the International Voluntary Market

An important source of potential demand for SFiM credits at the international level is the voluntary market. Moreover, given the strong co-benefits of SFiM projects there is potential for SFiM credits to sell for a premium in the voluntary market. Units from Gold Standard certified projects, for example, have been sold for anywhere between 50% and 500% above the CER spot price (Gold Standard, 2015), although this is still below cost price for Australian SFiM credits.

Since mid 2000s, voluntary buyers globally have purchased 844 $MtCO_2e$ in emissions reductions worth \$4 billion, at an average historical price of US\$5.9/tCO_2e (Forest Trends' Ecosystem Marketplace, 2015).

In 2013, the private sector bought 76 $MtCO_2e$ of carbon credits for a value of \$379 million at an average of US\$4.9/tCO_2e (Forest Trends' Ecosystem Marketplace, 2015).

Energy utilities were the largest consumers, purchasing 5 $MtCO_2e$ in 2013. Companies in the finance and insurance sectors purchased 4.4 $MtCO_2e$. The transportation sector – particularly aviation – purchased 3 $MtCO_2e$ (Forest Trends' Ecosystem Marketplace, 2015).

Offsets generated by forestry and land-use projects supplied the majority of these credits, totalling 27 $MtCO_2e$ transacted or a 45% the marketplace. REDD activities were the most popular individual project type, accounting for 23 $MtCO_2e$ – almost triple their transaction volumes from 2012 and topping 2010's record 18.7 $MtCO_2e$. REDD offsets' popularity was due in part to their lower average price of US\$4.2/tCO_2e, down from US\$7.4/tCO_2e in 2012. Afforestation/Reforestation (A/R) offset volumes fell dramatically by 70% to 2.6 $MtCO_2e$ from a record 8.8 $MtCO_2e$ in 2012, while Improved Forest Management (IFM) transactions also fell 67% to 1.2 $MtCO_2e$ (Forest Trends' Ecosystem Marketplace, 2015).

In 2013, carbon projects located in 59 different countries on every relevant continent successfully sold offsets to voluntary buyers hailing from 32 different countries. Projects in Latin America supplied the largest volume of offsets – primarily from forestry activities (Forest Trends' Ecosystem Marketplace, 2015).

In 2013, the Verified Carbon Standard (VCS) was the most used third-party standard with 28.9 $MtCO_2e$ or 47% of 2013's total volume. More than a third of transacted VCS tonnes additionally achieved certification to the Climate, Community and Biodiversity (CCB) Standards (9.6 $MtCO_2e$) or the SOCIALCARBON Standard (1.3 $MtCO_2e$), as buyers continued to show interest in offsets with certified non-carbon benefits. Projects utilising these non-carbon certifications reported slightly higher average prices than VCS-only offsets (Forest Trends' Ecosystem Marketplace, 2015).

VCS experienced the most dramatic average price decrease, down by 46% to an average of US\$2.8/tCO_2e, with some tonnes bought for less than 5c/tCO_2e. REDD+ offsets, which made up 9.6 $MtCO_2e$ of VCS's volume, sold at an average of US\$3.2/tCO_2e– above many other project types, but still below market-wide average pricing. Non-carbon certifications CCB and SOCIALCARBON also tended to add value to VCS offsets averaging US\$3.8/tCO_2e (Forest Trends' Ecosystem Marketplace, 2015).

Projects adhering to the Gold Standard saw 9.3 $MtCO_2e$ transacted, just 2% less volume than last year. The Gold Standard's average price remained higher than the market's overall average ($8.5/ tCO2e versus $4.9/tCO2e), but was down 9% from 2012's $11.2/tCO2e (Forest Trends' Ecosystem Marketplace, 2015).

VCS and Gold Standard are developing new standards that are more related to SFiM. VCS has two methodologies that can be used to measure carbon reduction from the better management of fire: VM0029 Methodology for Avoided Forest Degradation through Fire Management, and v1.0; VM0032 Methodology for the Adoption of Sustainable Grasslands through Adjustment of Fire and Grazing.

MCDI developed VM 0029, which was adopted in April 2015. The MCDI is developing a Project Design Document. MCDI plans then to undergo project validation by one of the VCS verification bodies will compliment the VCS certification with parallel certification of biodiversity and social safeguards under the Climate, Community and Biodiversity Alliance (CCBA) Standard. It is hoped to have certification by VCS and CCBA in 2016. MCDI and Carbon Tanzania will be marketing the forest carbon offsets generated on this project for the benefit of the forest communities involved (MCDI, 2015).

The Gold Standard Secretariat is currently expanding its Programme to include land use activities, and has indicated an interest in certifying a SFiM methodology for the Australian and international SFiM context (pers.comm Gold Standard).

Climate Action Reserve (CAR), Plan Vivo and Climate, Community and Biodiversity Standards provide potentially important standards for SFiM projects for use in the voluntary markets.

Private registries have become an important mechanism for international credits developers looking to list credits and potential buyers sourcing credits. Some relevant examples for SFiM projects include:

- The American Carbon Registry;
- The APX VCS Registry, that provides a registry for issuing, tracking and retiring Verified Carbon Units (www.vcsregistry.com);
- The Carbon Catalog, a free and independent directory of carbon credits, listing carbon providers and projects worldwide (www.carboncatalog.org).
- The Climate Action Reserve;
- The Carbon Trade Exchange (CTX), that provides exchanges in multiple global environmental commodity markets, including Carbon, Renewable Energy Certificates (RECs) and Water (http://ctxglobal.com/markets/voluntary-carbon/); and

- Markit, that provides a registry for carbon, water and biodiversity credits (www.markit.com).

The Non-State Actor Zone for Climate Action (NAZCA) which registers commitments to action by companies, cities, subnational regions, and investors to address climate change and the Lima-Paris Action Agenda (LPAA), which has transformational initiatives, may also become important sources of market information and demand.

At the corporate level, there is evidence of increased planning for carbon pricing, which provides opportunities for SFiM projects to sell carbon credits. At least 150 companies use an internal carbon price, as reported by the Carbon Disclosure Project (CDP), with disclosed prices ranging from \$6 to \$89/tCO2e. These companies represent diverse sectors of the economy, including the consumer goods, energy, finance, industry, manufacturing, and utilities sectors (CDP, 2014).

Some of these companies have committed to purchase significant offset volumes from projects overseas as part of their corporate strategies. Microsoft has contracted offsets from over 20 carbon-offset projects in countries such as Brazil, Cambodia, Ghana, Guatemala, India, Indonesia, Kenya, Madagascar, Mexico, Peru, and Turkey. Companies have shown a particular affinity for REDD+ projects, with Disney donating \$3.5 million to a Conservation International REDD+ project in the dwindling Alto Mayo Protected Forest in Peru that has generated 3 MtCO2e and delivered a host of benefits for local populations. "We like projects that have co-benefits and side benefits in addition to just pure GHG benefits," said Bob Antonoplis, Assistant General Counsel for The Walt Disney Company. "We're really drawn to forestry projects and we're really drawn to reforestation projects in particular that have watershed protection, habitat rehabilitation as well as a GHG component." (CDP 2014). SFiM projects would meet all these criteria.

There are also examples of where companies are purchasing offsets to meet voluntary emissions commitments. For example, the Brazilian cosmetics giant Natura Cosméticos purchased 120,000 tCO2e of carbon offsets from the Paiter-Suruí, an indigenous people of the Amazon who in June 2013 became the first indigenous people to generate offsets by saving endangered rainforest using the VCS REDD standard. The region's largest cosmetics manufacturer committed to reducing its GHG emissions by one-third from 2006 levels by the end of 2013 and has offset 100% of its emissions since committing to carbon neutrality in 2007.

The interest in the standard setting agencies such as VCS and Gold Standard in developing methodologies for SFiM projects reflects a judgment by these agencies that there is sufficient interest in the voluntary market for SFiM credits.

Other sources of support for SFiM Projects

SFiM activities in developing countries could also be funded through international climate finance as Nationally Appropriate Mitigation Actions (NAMAs) and National Adaptation Programme of Actions (NAPAs). In 2009 the UNFCCC Conference of the Parties in Copenhagen agreed to the goal of jointly mobilising US$100 billion per year by 2020 to assist developing countries to undertake mitigation and adaptation action. Climate finance from donor to developing countries is up from US$52 billion in 2013 to US$62 billion in 2014 and appears to be on track to meet the Copenhagen commitment (OECD, 2015). As climate finance continues to grow, it will be a potential source of support for SFiM projects in developing countries – whether as NAMA or more traditional climate finance projects.

Given the strong development benefits of SFiM projects, they could also potentially be funded as development projects through Official Development Assistance initiatives such as the International Climate Initiative, and through philanthropic initiatives. A review of the funding policies of the major aid agencies by this Initiative found that SFiM projects meet the substantive criteria of most aid agencies and donors.

The International Savanna Fire Management Initiative has had extensive interest and discussions with USAID, GIZ, IKI, JICA, NORAD, DFID, SIDA, AFD, KfW, UNEP, UNDP and the World Bank. The Initiative also had extensive discussions with many major philanthropy foundations including: The David and Lucile Packard Foundation, The Oak Foundation, The Rockefeller Foundation, Gordon and Betty Moore Foundation, Rockefeller Brothers Fund, Inc., Ford Foundation, Tides Foundation, Wallace Global Fund II, The John D. and Catherine T. MacArthur Foundation, the Scholl Foundation, Charles Stewart Mott Foundation, The Christensen Fund, The MAC Foundation, The Tinker Foundation Inc., W. K. Kellogg Foundation and the J. M. Kaplan Fund. All these funders agreed that SFiM projects met their basic criteria, agreed there was great potential for SFiM projects and that they could play an important role in addressing climate change as well as many other conservation and development issues. Despite this none were in a position to support or invest in any proposal at the current time.

One important example of the Initiatives' attempts to secure funding from a donor is the Green Climate Fund (GCF). SFiM projects meet the substantive criteria for support from the GCF. The GCF is only just establishing its policies. The policies developed so far and potential support for a project is centred on a national priority setting process led by the National Designated Authority (NDA) NDA in each country. Most countries are still in the preliminary stages of developing their priorities for the GCF. The extensive technical requirements of the GCF criteria have favoured priorities focusing on large infrastructure oriented projects. Nevertheless, there are opportunities for SFiM projects if they become actively involved in the national consultation process and work with their relevant NDA.

Recently, bonds have been issued specifically as "green" or "climate" bonds. Those financial instruments have been successful in developing a green bond market that helps to mobilize private sector funding for environmental projects and, ultimately, to raise awareness about climate finance opportunities in the capital markets. In 2013, issuers raised in aggregate more than US$11 billion through bonds explicitly tagged as "green bonds". As this new market grows, it expands to more issuers and types of products across the risk spectrum. Despite consideration by the Initiative and interest from SFiM projects in this type of investment, no bond has been proposed or issued that would support the development of an SFiM Project or other similar type of projects such as a REDD+ credit. Although many SFiM projects have thought about investments instead of grants as a way of finding financial support, none have conclude that such a mechanism is viable. This may be due to a state of mind as much as a financial realty. There does, however, seem to be some interest in Australian context to at least explore this possibility with at least one philanthropic foundation interested in investigating this possibility further.

Conclusions

The most important demand for SFiM credits so far has been the Australian ERF. These credits have developed and underwritten the development of almost all of the SFiM projects in Australia. The recent successful auction where 34 contracts for nearly 7m tonnes of ACCU were issued for SFiM projects means that the ERF will be the main market for these credits for the foreseeable future.

The private sector's demand for SFiM credits, or at least the co-benefits from these credits, remains an important option for SFiM projects. For SFiM projects outside of Australia, given the dynamic nature of carbon markets, the voluntary markets will be the most important source of demand in the short term. The flexibility of these arrangements, in particular, a willingness to value the co-benefits of SFiM and to also consider long-term relationships, further enhances the attractiveness of this market and its demand. Resource companies have led the way in supporting SFiM projects to date and are interested in developing this leadership more. Internal pricing mechanisms being adopted by many companies could potentially create more demand and opportunities for SFiM Projects. A major challenge that most SFiM projects face in developing this opportunity is finding the right company or a reliable trustworthy intermediary such as a broker. Another is being able to communicate effectively with companies, or, in other words, to translate their local based skills into the corporate world of accounting terminology.

REDD+ also provides some interesting opportunities for SFiM projects that can also include tropical forests into their projects. Volume and prices would be sensitive to similar issues as outlined above for marketing SFiM project directly to companies.

Long term demand and stability for the market will be driven by the timing and ambition of future climate policies, the importance of markets in delivering these targets, and the ability to implement the relevant policies (supply and demand side) effectively. As a result the uncertainty and heterogeneity of the demand and market seem likely to continue for the foreseeable future. Indeed, most countries recognize that the large uncertainties in future international credit demand mean that they cannot count on a high volume or high price for credits sold, at least in the near term.

The volatile and varying nature of demand further emphasises the importance of seed funding for new SFiM projects to assist them to develop viable SFiM projects. Although the level of capacity varies among these various communities and governments that the Initiative worked with, none have the resources to develop viable proposals for SFiM projects without some seed funding. Also the vast majority of the holders of the relevant experience and knowledge in Australia, such as the Traditional Owners across Northern Australia, have the resources to support the export or transfer of this know how. Access to this type of funding will be needed to progress pilot projects in developing countries.

Practical steps to help SFiM projects promote demand and access markets would include:-

- Regular exchanges between SFiM projects to allow for market intelligence to be exchanged and to address the asymmetry in capacities between the suppliers and buyers.
- Developing an international methodology through, for example, the Verified Carbon Standard (VCS) or Gold Standard (GS), to enhance and promote demand for SFiM credits.
- Supporting efforts to link carbon markets and allow the use of international credits thereby allowing SFiM projects in developing countries to access carbon markets in developed countries.
- Promoting Emissions Reduction Fund type developments in national carbon markets.
- Exploring innovative market solutions, and facilitating/brokering partnerships between producers and the private sector.
- Developing models that value and price associated co-benefits.

- Supporting efforts to raise awareness among donors.
- Undertaking an expert analysis of the bond market.
- Developing an international platform or registry for SFiM projects, within one of the existing registries.
- Establishing significant and long-term leadership by governments to support the development of an SFiM network.

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