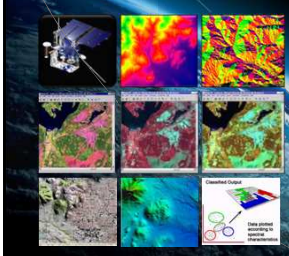
International Center for Agricultural Research in the Dry Areas
Science for better livelihoods in dry areas

ICARDA

Applications of geo-informatics in cactus pear research and development

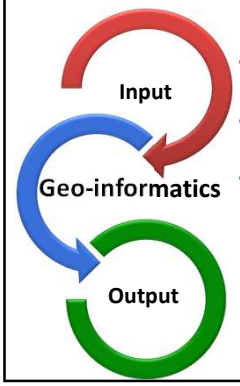


Mounir Louhaichi, PhD, GISP
Landscape Ecologist

Biradar Chandrashekhar (ICARDA
Douglas E. Johnson (OSU)

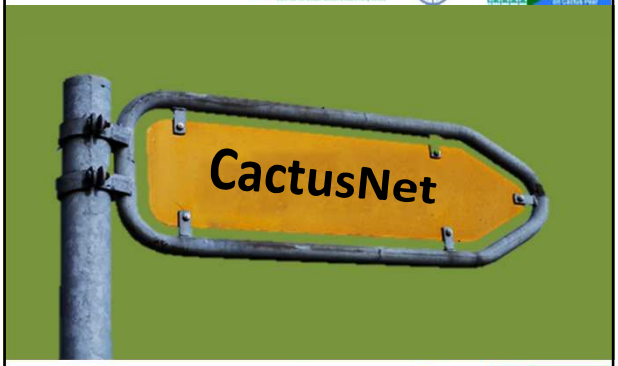
|m.louhaichi@cgiar.org|

Outline



- **Introduction**
  - CactusNet
- **Geo-informatics**
  - GIS, RS, GPS
- **Illustrations of few examples**
  - GPS: Mapping
  - GIS: Suitability (modeling)
  - RS: VegMeasure, Lidar

CACTUSNET ICARDA



CACTUSNET ICARDA

http://www.cactusnetwork.org/home.html

CACTUSNET ICARDA

FAO-ICARDA INTERNATIONAL TECHNICAL COOPERATION NETWORK ON CACTUS

Home Events & Meetings Publications Gallery Contact

Cactusnet is an international technical cooperation network on cactus created in 1993 by the FAO and ICARDA.

The FAO-ICARDA CACTUSNET is establisked on voluntary basis, and aims to :

-Collect and disseminate information on cactus production

-Facilitate the collection and utilization of germplasm.

-Promote the ecological and social benefits of cactus pear.

-Develop new food and carminic acid uses.

-Work with national partners to improve technical capability.

Cactus as a sustainable and versatile plant for the dry areas

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Drylands thinking
Solutions and new perspectives on drylands agriculture

ICARDA

Home About Submission

Cactus: a sustainable and versatile plant for the dry areas

Created on June 23, 2014

Topics
Crop science
Farming practices
Gender
Livestock
News/Comments - Drylands

Increasing demands on already-scarce water resources across the world's dry areas require alternative sources of animal feed – specifically crops that are more efficient uses of water. One alternative with the potential for widespread production is cactus. ICARDA is now actively promoting this high-energy, nutrient-rich plant as a versatile crop with multiple applications.

With its high water efficiency and content, cactus can sustain livestock through the driest of seasons. A well-developed root system also allows these versatile plants to grow in marginal areas where other forage species often fail. Compared to many other crops and fodder, cactus is easy to establish, maintain, and utilize.

The plant generates a high biomass of green forage – ranging from 30 to 250 tons (fresh cladodes) per hectare in semi-arid areas – which is packed full of essential nutrients, reducing the intense pressure that livestock might otherwise exert on scarce water resources and other rangeland plant species.

Several studies have further demonstrated the additional economic gains that can be generated by incorporating cactus cladodes into ruminant diets, such as improved meat quality, which results from an increase in the proportion of conjugated linoleic acid.

http://icarda.org/drylandsthinking/Cactus-sustainable-and-versatile-plant-dry-areas

Exchange of Germplasm
Legal channel

ICARDA

Phyto-sanitary Certificate

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Introduction of cactus accessions from Italy and Brazil

2014

ITALY
Total number of accessions: 15
Number of Pads/accession: 6

India and Pakistan

BRAZIL
Total number of accessions: 25
Number of Pads/accession: 5

Jordan, India, Pakistan and Italy

CGIAR RESEARCH PROGRAM ON Dryland Systems

India

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Assessing adaptability and utilization potential of *Opuntia ficus-indica* in arid and semi-arid regions of India

IGFRI in Jhansi

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India

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- CAZRI was our partner from India
- Rajasthan state: High temperature

Respect agro-ecological characteristics for optimum growth
Put right plant in the right place

Out-scaling strategy

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- **Identification of suitable cactus material for a specific location/objective**
- **Multiplication of material at local level (mother cladodes)**
- **Establishment of Cactus Growers' Cooperative/Association similar to orchard growers' cooperative**

Pakistan

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Enhancing the use of cactus (*Opuntia ficus indica*) to promote better livelihoods in arid areas of Pakistan

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Pakistan

ICARDA

Farmer's day on the introduction of spineless cactus was held on 15th May, 2014

Enhancing the use of cactus (*Opuntia focus indica*) to promote better livelihoods of pastoral and agro-pastoral communities in arid areas of West Asia

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CACTUSNET ICARDA

Country of Origin	No
Italy	46
Brazil	25
Tunisia	24
Mexico	13
Algeria	9
Morocco	6
New Mexico	6
Argentina	4
Others	18
Total	151

Cactus accessions were introduced from to **Jordan**

Establishment of cactus gene field bank with more than 150 accessions

ICARDA and Cactus-Net

ICARDA

Visit of Prof. Paolo to Jordan

CACTUSNET ICARDA

PhD Student Sawsan Hassan

ICARDA

UNIVERSITÀ DEGLI STUDI DI PALERMO

The Influence of soil volume (Root Confinement) on root and canopy growth, root turnover and canopy versus root ratio of *Opuntia ficus-indica*

The influence of planting methods of *Opuntia ficus-indica* on root and canopy growth, root turnover and canopy – root ratio

CACTUSNET ICARDA

MSc. Student Meriam Nefzaoui

ICARDA

Universidade Federal Rural De Pernambuco

Brazil

Comparative study of genetic variability of cactus accessions from North East Brazil and the Mediterranean Basin

- Better understanding of the existing genetic diversity with the aim to implement a comprehensive program of selection and to identify promising accession facilitating their certification.
- Contribute to a better understanding of the effectiveness of the different molecular markers which is considered as a priority step toward management of cactus pear collection and a prerequisite for more effective breeding program.

CACTUSNET ICARDA

Cactus Pear in West Asia

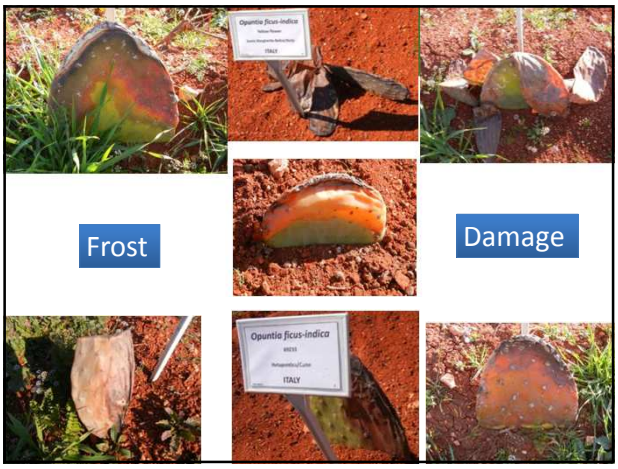
ICARDA

NA vs WA

Market price: 5.25 $/kg

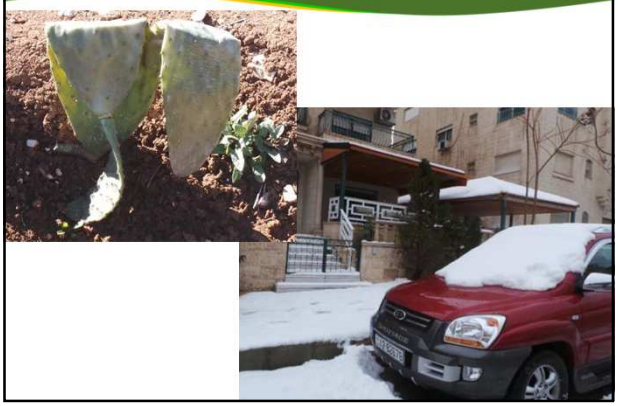
In West Asia cactus distribution is restricted primarily by the **freezing events** that occur during winter seasons (Le Houérou 1996).

Syria



Jordan

ICARDA



Screening for Cold-Tolerant Cactus Species

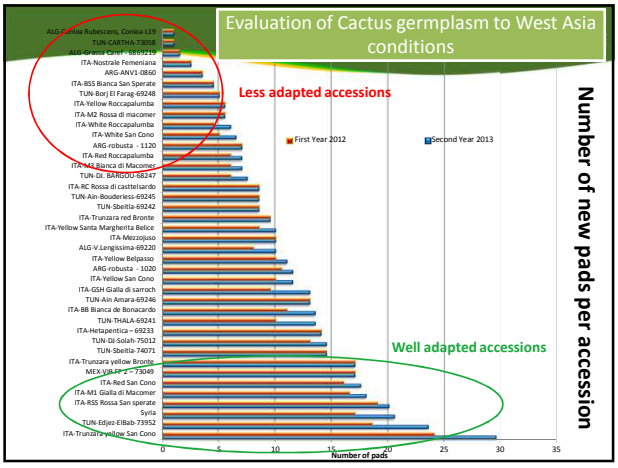
ICARDA

Study Objectives

- explore genetic resources with potential genes for adaptation to the adverse effects of climate change particularly night freezing temperature during winter season and
- evaluate agronomic practices such as date of transplantation on cactus establishment and vigour.

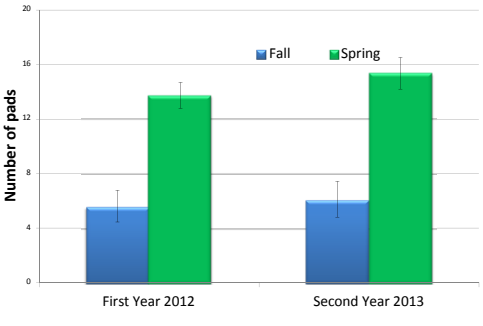
Hardy plant: come back

ICARDA



Season (timing) transplantation

ICARDA



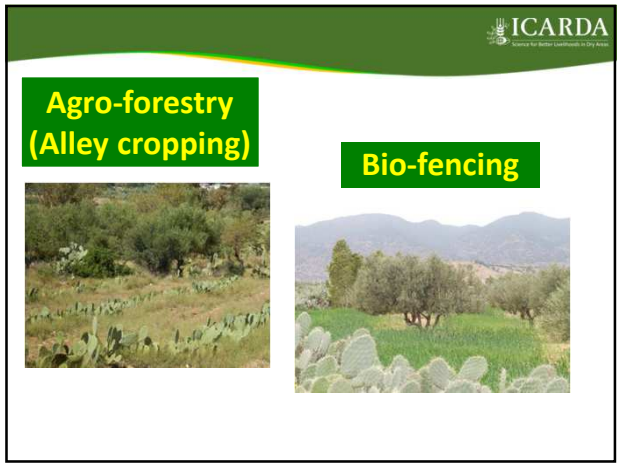
Screening for Cold-Tolerant Cactus Species

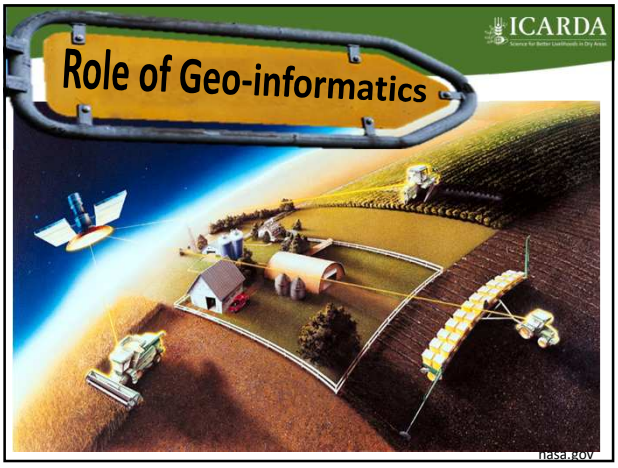
- Cactus is an important forage option to the drylands.
- **Key for sucessful establishement is to fit the right accession into the right agro-ecological environment.**

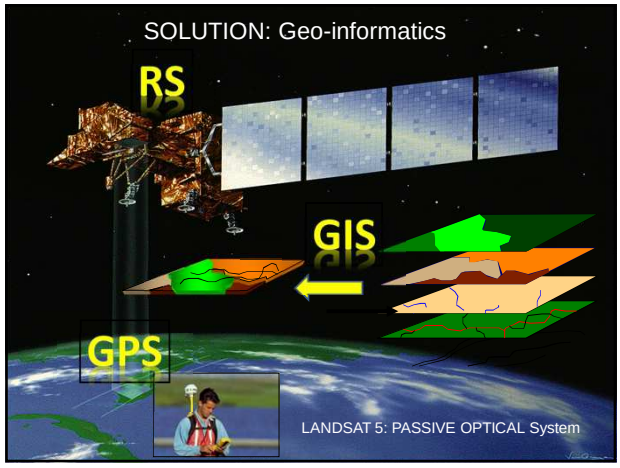
⬇

- Thus assessing adaptation of cactus accessions across a wide range of climates and agro-ecosystems is needed

http://dialogues.cgiar.org/blog/how-much-cactus-is-in-your-lipstick/

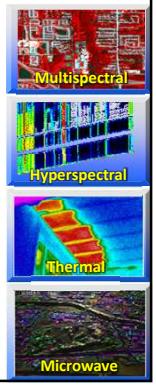






Geoinformatics in 21st Century

- Increased spatial, spectral and temporal resolutions
- Increased computational efficiency and speed
- Decreased hardware and software cost
- Decreased RS data cost



Spatial Resolution: Global to Local Scale

Satellite	Resolution(m)	Pixels/ac	Pixels/ha	$/km²
AVHRR	1000	0.004	0.01	Free
MODIS	500	0.016	0.04	Free
Landsat	30	4.5	11.1	Free
PALSAR	10	40	100	Free
NAIP-AP*	1	4046	10000	Free
AWiFS	60	1.11	2.7	0.01
IRS liss3	23.5	7.3	18.1	0.15
ASTER	15	18	44.4	0.04
IRS Liss4	5	160	400	1.19
RapidEye	5	160	400	1.23
IKONOS	4	253	625	5.02
Cartosat1	2.5	640	1600	6.59
GeoEye1	2	1012	2500	12.5
WorldView2	2	1012	2500	14.5

Landsat Continuity Mission: Landsat 8, Feb 11, 2013

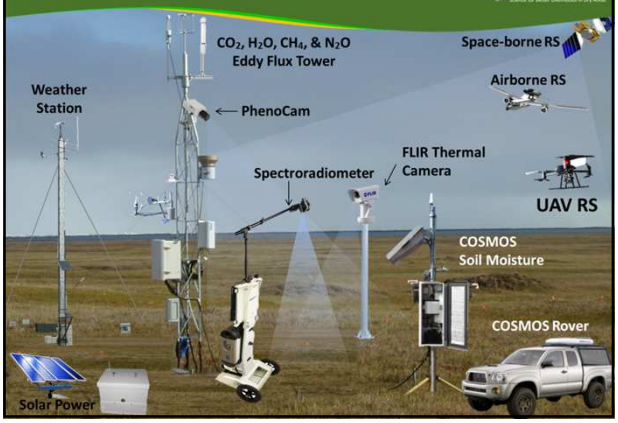
Remote Sensing of Agro-Ecosystems

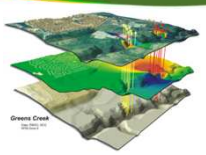
Innovation Systems

Example of One Sensor in each Platform

	Platforms	Ground/*In-situ*		Airborne		Spaceborne				
	Mode	Hyperspectral	Multispectral	Optical	LIDAR	Optical			LIDAR	SAR
RS data characteristics	Sensor	ASD FieldSpec	MK Camera	APS/UAVs	Lidar	WorldView-2	Landsat	MODIS	ICESat*	PALSAR
	Spectral	350-2500nm	4 bands	3-4 bands	1264nm	8 bands	7 bands	7/36 bands*	1264 & 532nm	L band
	Spatial resolution	0.1-1.5m	0.1-0.2m	1-m	20 - 80cm	0.46m Pan; 1.84m MS	15m Pan; 30m MS	250m, 500m, 1000m MS	70m	10m, 20m, 100m
	Swath	1-4m	2-10m	--	1-2km	16.4km	185km	2330km		35-250km
	Revisit	--	--	3-year	--	1.1 days	16 days	1 day	91 days	46 days
Biophysical	Plant biomass	×	×		×	×	×	×		×
	Plant height				×				×	×
	LAI, FPAR, LST	×	×			×	×	×		
	NDVI, EVI, LSWI	×	×	×		×	×	×		
Biochemical	Erosion, Salinity	×	×	×	×	×	×	×		
	Soil moisture	×	×	×		×	×			×
	Chlolophyll	×	×			×	×	×		
	Nitrogen	×	×	×		×	×			
	Phosphorous	×	×			×				
	Plant water	×	×			×		×		
Production	GPP	×	×	×				×		
	NPP	×				×	×	×		
LULC	land cover/use	×	×	×		×	×	×		×
	phenology	×	×				×	×		×
	irrigation	×	×	×		×	×	×		×
Terrain	DEM		×	×	×	×			×	×
	Derivatives		×	×	×				×	×
Scale	Tier 1 AOIs	×	×	×	×	×	×	×	×	×
	Tier 2 action sites	×	×	×			×	×	×	×
	Tier 3 AEZs	×	×	×				×	×	×
	Tier 4 Target			×				×		×

Integrated Earth Observation System





GEOGRAPHICAL INFORMATION SYSTEMS

GIS

GIS

"GIS is a collection of computer hardware, software, and geographic data for capturing, managing, analyzing, and displaying all forms of geographically referenced information."

Source: Longley et al (2005) *Geographic Information Systems and Science*. 2nd Edition. John Wiley and Sons Ltd.

GIS

ICARDA

Example # 1

GIS

ICARDA

Opuntia ficus-indica (L.) Mill. Suitability Mapping Utilizing the Refined KRESS Habitat Suitability Analysis Module

Model: KRESS

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- The model uses climatic, elevation, and other variables in a raster GIS format along with the positions of known plantations of Cactus (or any other plant) to define the environmental or niche tolerance of the plant.
- The niche tolerance of the plant is then applied to the area of interest to determine which sites most closely resemble the conditions under which Cactus thrives.
- The result is a theoretical suitability map for the area of interest (target).

R Programming

Modeling Process

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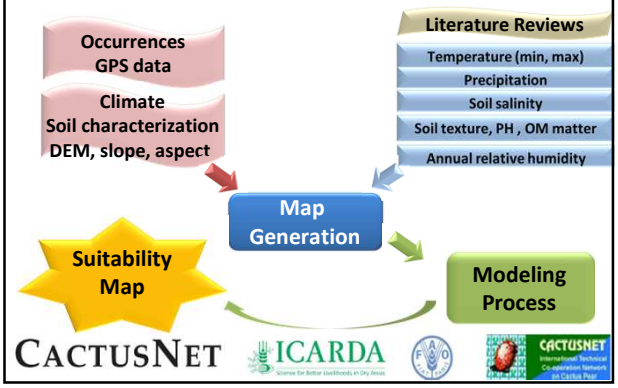

Cactus Plantation Position Data

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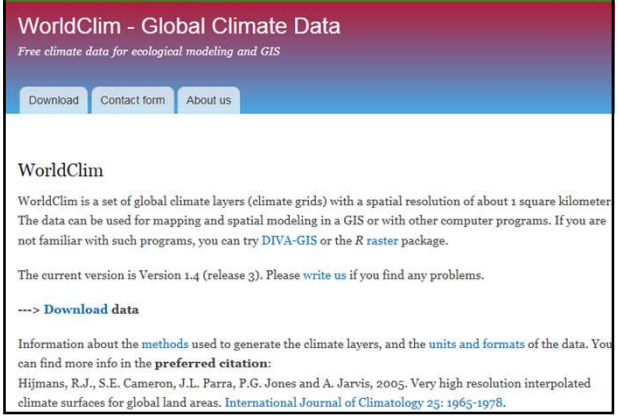
- **Plant Occurrence Data** is entered into the program as Simple ASCII Comma Separated Values (CSV) file where the position of each known stand of Cactus (or other plant) is Identified.
- Data files can be made in MS Excel and saved as a CSV File

Longitude	Latitude	Sequence	Species
10.09633	35.6781	1	Opuntia ficus-indica (L.) Mill.
9.1294	35.2297	2	Opuntia ficus-indica (L.) Mill.
9.5	35.0333	3	Opuntia ficus-indica (L.) Mill.
9.2058	35.8606	4	Opuntia ficus-indica (L.) Mill.
9.9	36.3667	5	Opuntia ficus-indica (L.) Mill.
10.15	36.4	6	Opuntia ficus-indica (L.) Mill.
8.8333	35.1667	7	Opuntia ficus-indica (L.) Mill.
10.0167	35.9333	8	Opuntia ficus-indica (L.) Mill.
9.37082	36.08497	8	Opuntia ficus-indica (L.) Mill.

WorldClim http://www.worldclim.org/

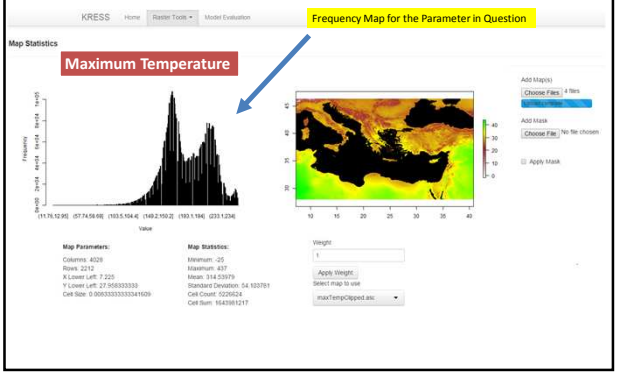
ICARDA



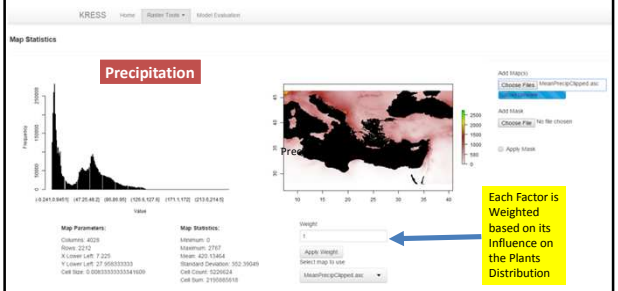
Modeling Process

- The Map Statistics Tool displays spatial parameters and statistics for any uploaded environmental variable.
- The data is processed into a frequency histogram stretched into 256 bins for comparison to other variables.
- A weight can be assigned to each variable depending on the role it plays in the plant's survival.

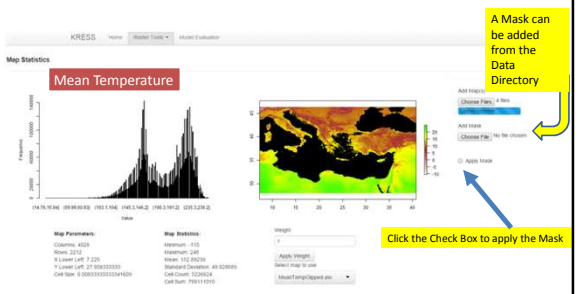
A Screen Capture of the Map Statistics Tool



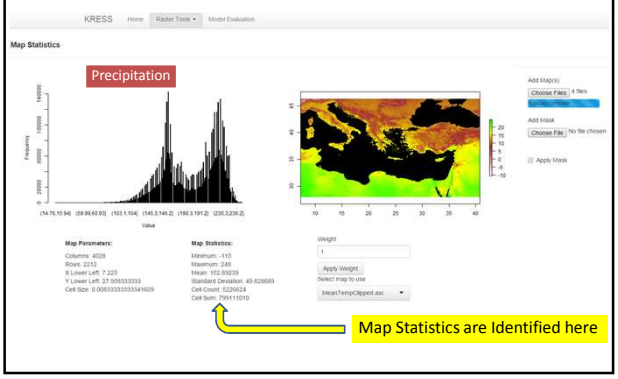
Each Factor is Weighted Based on its Importance



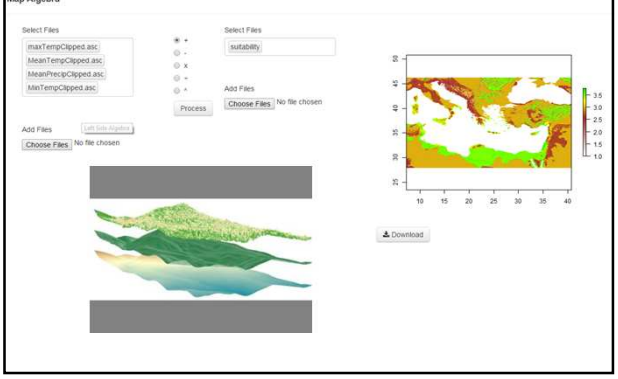
Area of Interest can be Masked



Map Statistics

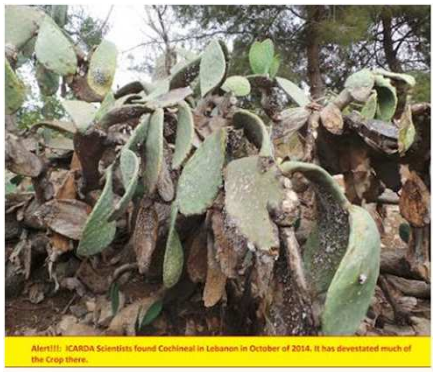


Map Algebra Issued to Generate a Suitability Model



Example
2

Spread of Cochineal in Southern Lebanon

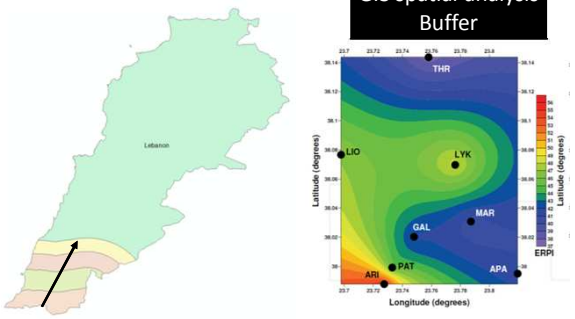


Spread of Cochineal in Southern Lebanon

Spread of Cochineal in Southern Lebanon

Spread of Cochineal in Southern Lebanon

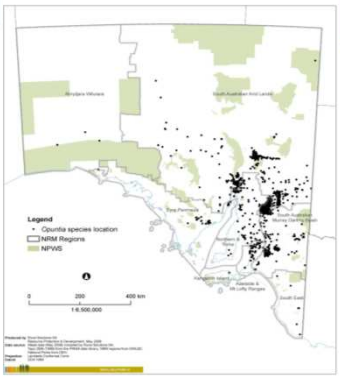
GIS spatial analysis
Buffer



Source: Panagiotis Nastos et al., 2011

Example
3

State distribution of Opuntioid cacti



State Opuntioid Cacti Management Plan

GPS locations: occurrence of *Opuntia* species

Source: Government of Southern Australia. State Opuntioid Cacti Management Plan (2009)

Risk Assessment (Australia)

2009, who stated

"Under the 2080 climate scenario, the state-wide risk for this species would shift southward as the climate suitability increases in the south and southeast of South Australia. It is likely that there are outlying populations to the south of those populations identified in figure 4. Under the future climate scenarios, these populations are likely to transform from benign populations to invasive as temperatures become more conducive for growth and reproduction."

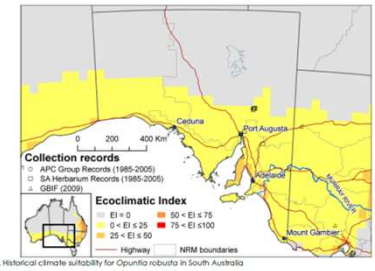


Figure 5.4. Historical climate suitability for *Opuntia robusta* in South Australia

Impact of climate change on the spread of *Opuntia robusta* in Southern Australia based on climate scenario

Source: Government of Southern Australia. State Opuntioid Cacti Management Plan (2009)

Risk Assessment

State Opuntioid Cacti Management Plan

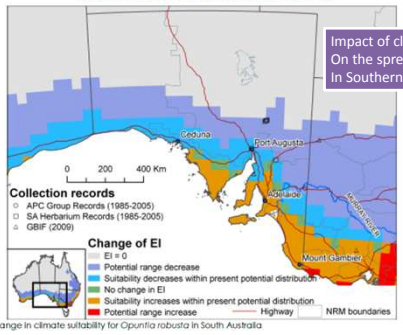
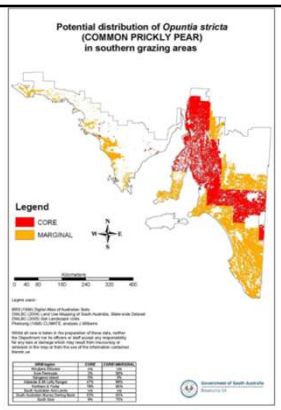


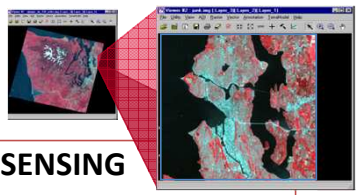
Figure 5.5. Change in climate suitability for *Opuntia robusta* in South Australia

Impact of climate change
On the spread of *Opuntia robusta*
In Southern Australia

Source: Government of Southern Australia. State Opuntioid Cacti Management Plan (2009)



The potential distribution of ***Opuntia stricta*** in grazing lands of the southern agricultural region of South Australia was modelled with available information in 2005.
These maps were produced by overlaying the results of a „**CLIMATE**" modelling analysis while **removing areas poor drained soils.**

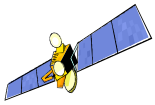


REMOTE SENSING

RS

Remote Sensing

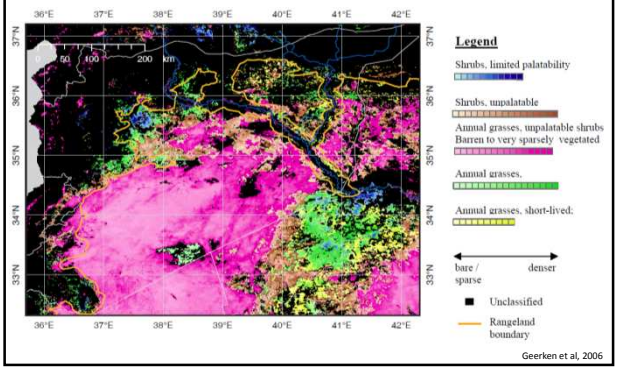
Remote sensing is the acquisition of information about an object or phenomenon without making physical contact with the object and thus in contrast to on site observation.



Exp: MODIS Based Grassland Classification

ICARDA

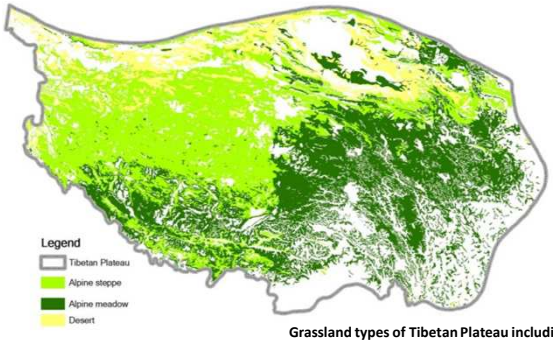
Forage Quality



Geerken et al, 2006

Exp: Grassland types in the Tibetan Plateau, China

ICARDA

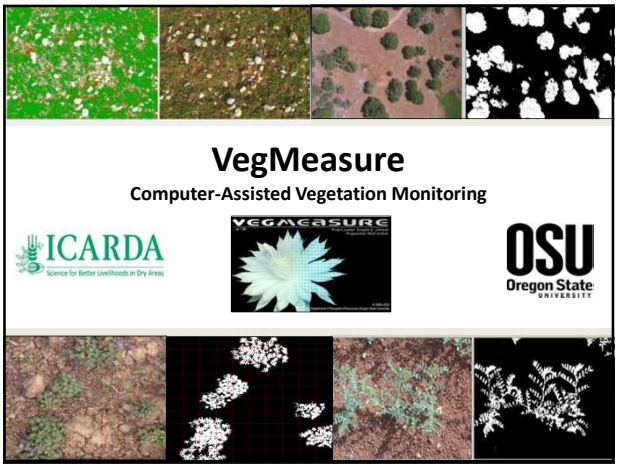


Grassland types of Tibetan Plateau including Alpine steppe and Alpine meadow.

Acquisition RS data (timing)

ICARDA

- Cactus is an evergreen plant when compared to others species it can be distinguished (spectral reflectance).
- Large plantations can be mapped even from google earth (free)



VegMeasure

Computer-Assisted Vegetation Monitoring

ICARDA

OSU Oregon State University

Digital Vegetation Charting

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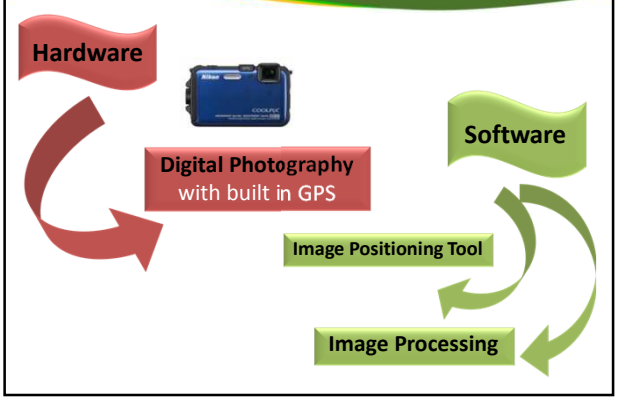

Measure surface area, length, width

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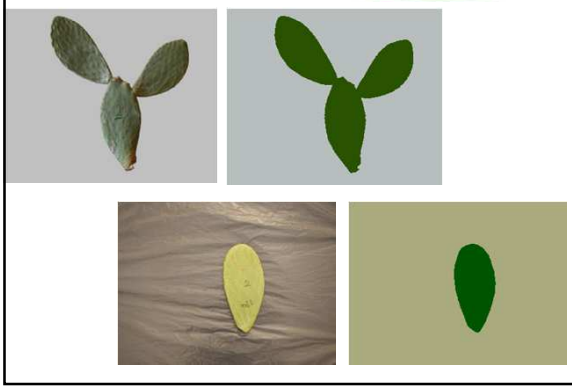

GIS Layers – Spatial analysis

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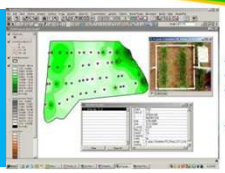
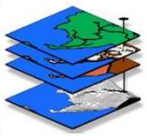
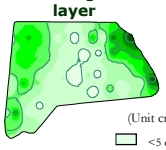
Geo-database





Perennial grasses layer



- Vast areas can be mapped quickly and objectively.
- Users do not have to be remote sensing specialists or GIS experts.
- For each agro-ecological site (same plant community) only few images are used to calibrate the software (threshold or training sites). Then the software can analyze hundred of pictures in just few minutes, summarize data and save it as a CSV format.
- Document the effects of year-to-year variation in weather on vegetation dynamics
- Characterization of key indigenous species
  -Extract environmental variables and model (predict) where identified species may grow

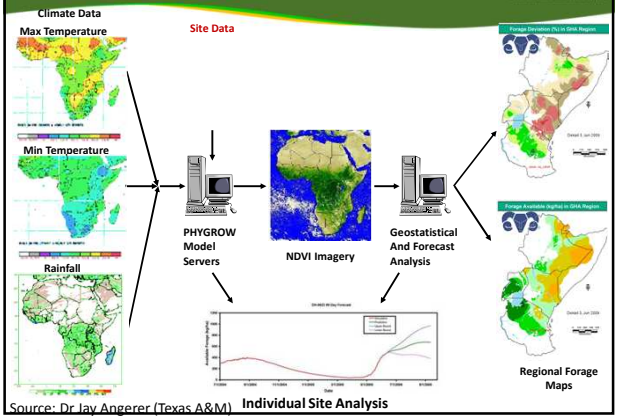
VegMeasure Mobile

ICARDA

- **Crowdsourcing** is the practice of obtaining needed services, ideas, or content by soliciting contributions from a large group of people, and especially from an online community, rather than from traditional employees or suppliers

Early Warning System Framework

ICARDA



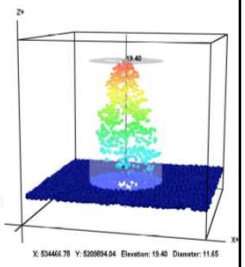
Source: Dr Jay Angerer (Texas A&M)

Lidar: Light Detection And Ranging

ICARDA

Light detection and ranging (LiDAR) is powerful remote sensing technology for quantifying the structure and dynamics of trees/shrubs (cactus) at large spatial.

A laser that measures distance by zapping a surface with light and grabbing its reflection up to 500,000 times a second; an imaging spectrometer, which can scope out the chemical composition of leaves; and a zoom lens to identify individual leaves' shape and orientation.



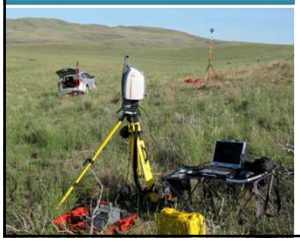
Lidar-based measurement of individual tree height within a Ponderosa pine stand, Fort Lewis Military Reservation, WA (source USGS)

LIDAR: LIGHT DETECTION AND RANGING

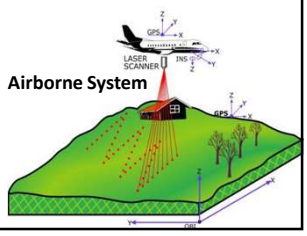
ICARDA

Laser remote sensors	• LiDAR uses laser light to estimates forest height/vertical structure • Ex: Carbon 3-D satellite system combines Vegetation canopy LiDAR (VCL) with horizontal imager	• Accurately estimates full spatial variability of forest carbon stocks • Potential for satellite-based system to estimate global forest carbon stocks	• Airplane-mounted sensors only option • Satellite system not yet funded • Requires extensive field data for calibration • Can be expensive and technically demanding

Terrestrial Laser Scans (TLS)

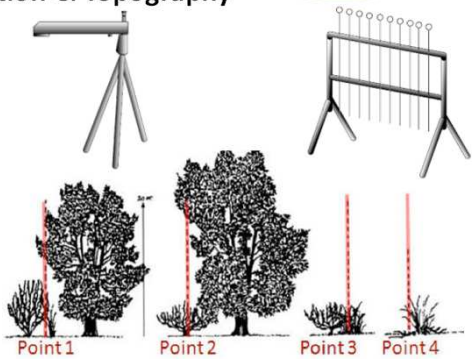


Airborne Laser Scans (ALS)



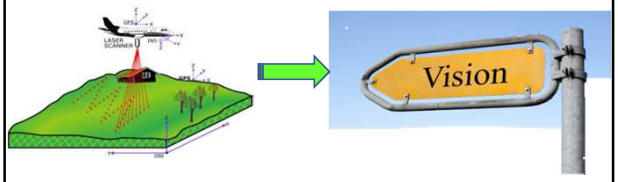
Point Intercept Methods for Vegetation & Topography

ICARDA



Allometry (a scaling function)

- Allometry is all about studying the relative sizes of plant parts. Usually, relationships between dbh (diameter at breast height), tree height, total biomass, etc., are calculated.



Above-ground Biomass = Tree Height x Allometric Equation

Take home messages

With the recent advances in geo-informatics a lot of opportunities

- Mapping surface area
  - Large plantation (surface area: ha) RS
  - Fencing (linear: km) GPS
- Time change analysis (RS)
- Risk assessment (predict where species may invade)
- Suitability for outscaling cactus
- Value chain (cactus plots, access to market,etc)

Acknowledgements

- UFS South Africa
- Cactus pear team
- FAO
- Government of Mexico
- Cactus Net scientists