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ID. 32260 Surveillance of Vector-Borne Diseases

Remote Sensing Monitoring of Vector-borne Diseases ——Schistosomiasis and Malaria

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OUTLINE

Background and Objectives

Current Research Progress

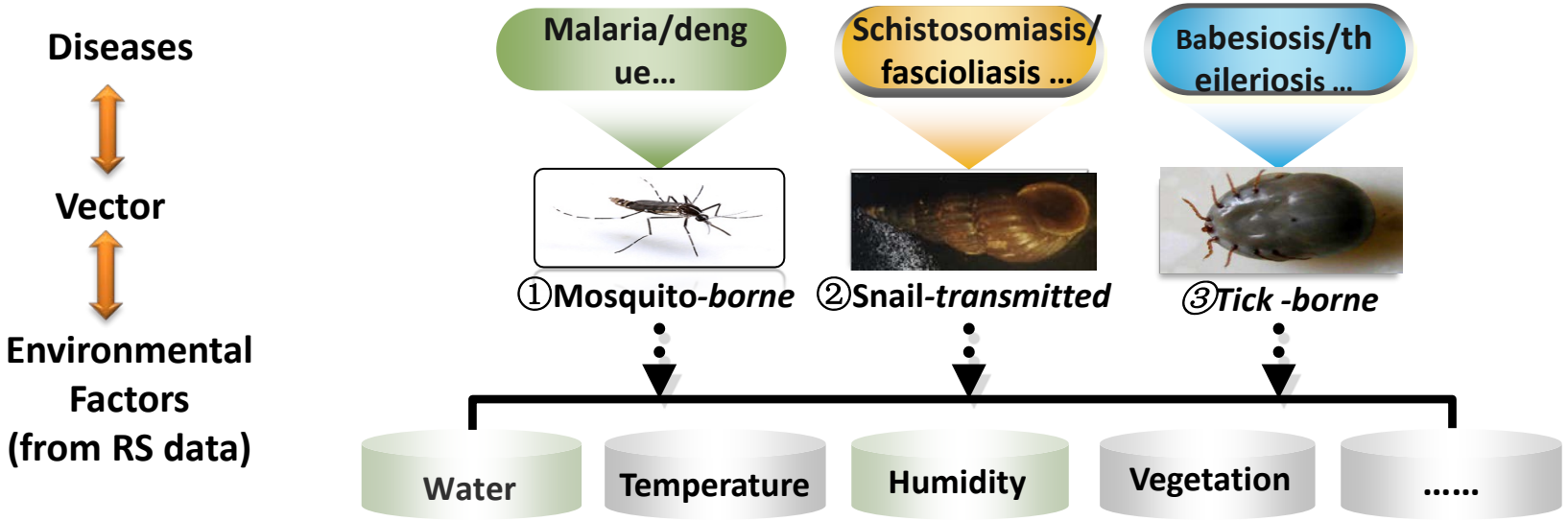
- Vector of Schistosomiasis-snail
- Vector of Malaria-Mosquito

Summary

Future works

Background

Monitoring and controlling the vector is extremely important and necessary way to reduce the transmission risk of vector-borne diseases. The survival of the vector is governed by various environmental factors . **The aim of project** is combine remote sensing technology with data mining to extract environmental factors and analyze the intrinsic link between the environmental factors and disease vectors, establish the RS model of vector in order to dynamically monitor and early warning the vector-borne diseases.



ID. 32260 Surveillance of Vector-Borne Diseases

Background

Research contents

1、Identify the remote sensing parameters related to vector-borne diseases based on the analysis of biological characteristics ;

2、Extract environmental factors from multi-source remote sensing data which are related to the transmission of vector-borne diseases ;

3、How to develop a RS model of vector-borne diseases , which reflect the relationship between environmental factors and diseases vectors, dynamically monitor and early warn the vector-borne diseases.

4、Use a case study to validate the effectiveness of the methods developed for dynamical monitoring and early warning of vector-borne diseases.

RS

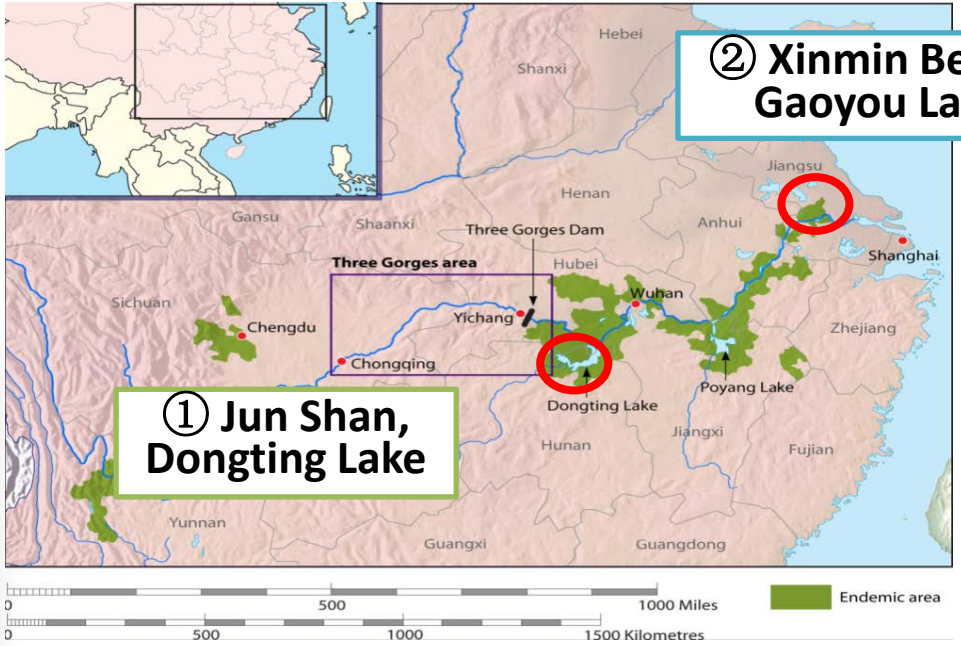
Model

Validation

Biologic characteristics

Current Research Progress

1、Snail-transmitted disease——Schistosomiasis



Map of schistosomiasis epidemic regions of China

Snail-transmitted disease-Schistosomiasis(Dongting Lake)

Case study area: Jun Shan, Dongting Lake

Environment of snail	Characteristics
Types of distribution	Lake type
Influence of water distribution	Winter Land, Summer Water
Time of medication and field survey	Spring(April) and Autumn (September)
Temperature	suitable breeding Below 20℃ or above 25℃, it will grow slowly
Elevation	20-35m(between Low water lever to flood line)
Vegetation	Cover the sunshine, adjust humidity
Water	Necessity, too little or drown, it will die
Soil, Sunshine, food, oxygen	… …

(a) Environment suitable for snail breeding

(b) Environment unsuitable for snail breeding

Two questions: 1 Identify RS Environmental parameters
2 how to model the complex link between RS environmental parameters to snail survival.

Snail-transmitted disease-Schistosomiasis

Identify RS Environmental parameters

ID	Environmental factors of snail	RS parameters	Satellite/ sensor	Spatial resolution
1	Water	NDMI(Normalized difference moisture index)	Landsat , TM/ETM+	30m
2	Vegetation	NDVI(Normalized Difference Vegetation Index)		
3	Soil	Tasseled Cap transformation _Wetness		
		Tasseled Cap transformation _Brightness		
		Soil moisture	ENVISAT ,ASAR	
4	Terrain	DEM	Terra, ASTER	
5	Temperature	LST(Land Surface Temperature)	Terra/Aqua, Modis	1km

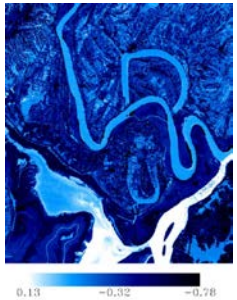
EO Data acquisition

ID	Satellite/sensor	Year(April)
1	Landsat , TM/ETM+	2003,2005,2007-2009
2	ENVISAT ,ASAR	2005,2007,2009
3	Terra/Aqua, Modis	2002~2009
4	Terra, ASTER	–

Snail-transmitted disease-Schistosomiasis(Dongting Lake)

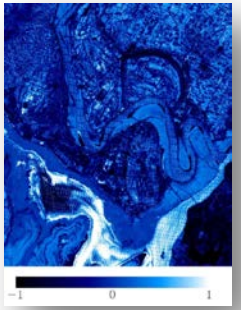
Environmental parameters retrieval from RS data

NDVI(Normalized Difference Vegetation Index)



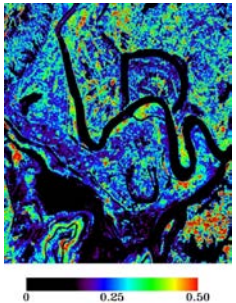
Tasseled cap transformation _Wetness

Tasseled cap transformation _Brightness



NDMI(Normalized difference moisture index

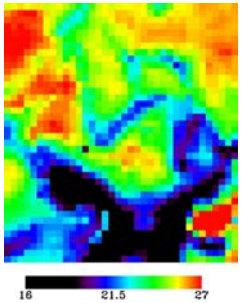
From Landsat TM/ETM+ (2009.04.15)



Soil moisture

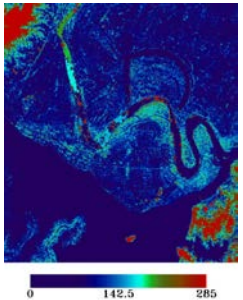
Water distribution

From ENVISAT-ASAR (2009.03.2)



LST (Land Surface Temperature)

From MODIS (Average of April ,2009)



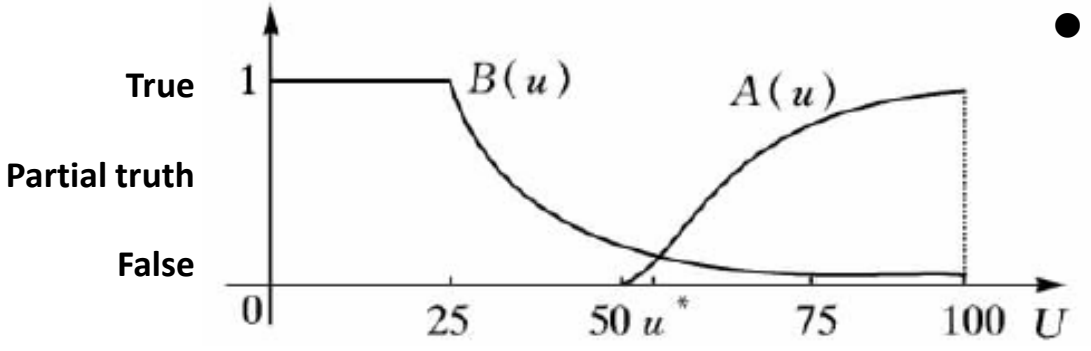
DEM

From ASTER

Snail-transmitted disease-Schistosomiasis(Dongting Lake)

Fuzzy theory- ***model the complex link between RS environmental parameters to snail survival***

- **Fuzzy theory is a form of probabilistic logic, and it deals with complicated matter that is approximate rather than fixed and exact by building membership functions.**
- **Takagi-Sugeno (T-S) fuzzy model is described by fuzzy IF-THEN rules， which can express relations of a nonlinear problem by a linear model.**

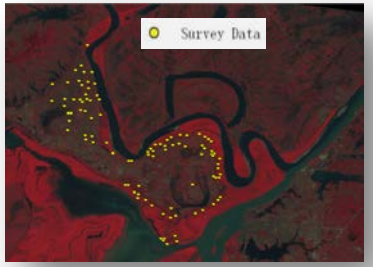


Membership functions

- **The T-S fuzzy model provide a better method to explore the relationship between snail density and remote sensing environmental parameters, and build a snail prediction model by only using remote sensing data.**

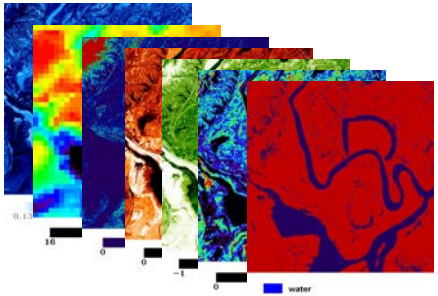
Snail-transmitted disease-Schistosomiasis(Dongting Lake)

Quantitative suitability relationship between snail breeding and RS environmental parameters:

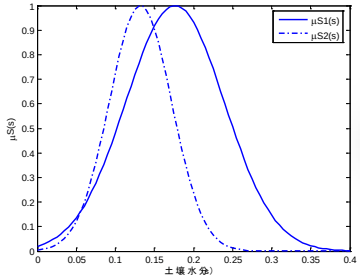


Survey data of living snail density

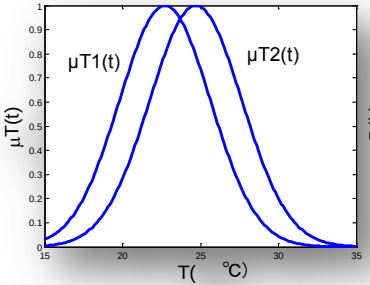
Fuzzy theory



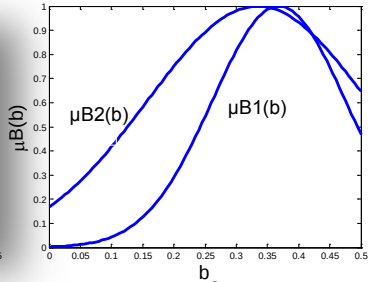
Retrieval environmental parameters images



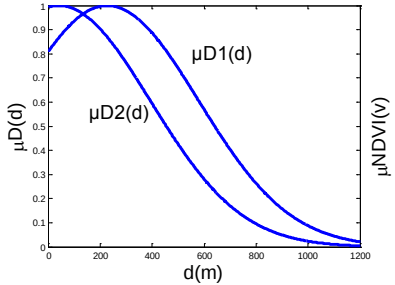
Soil moisture



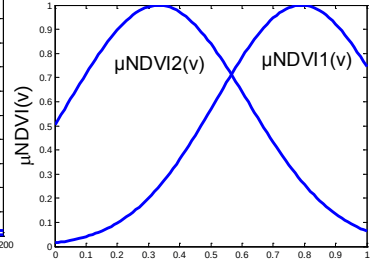
LST



TC_Brightnes



Distance from water



NDVI

Membership functions of RS environmental parameters

Snail-transmitted disease-Schistosomiasis(Dongting Lake)

RS model based on T-S Fuzzy :

Fuzzy rules:

(1) If(d is μD1)and(t is μT1)and(m is μMI)and(b is μB1)and(v is μNDVI1) then (u is u1)

(2) If(d is μD2)and(t is μT2)and(m is μMI)and(b is μB2)and(v is μNDVI2) then (u is u2)

where u1=-0.006407d - 0.1846t +1.925m + 0.1168b - 0.995v+15.689

u2=0.0644d + 0.1957t + 0.08948m + 0.407b - 0.4411v - 4.476

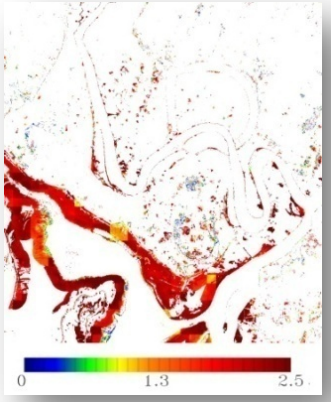
RS model :

$$u = \frac{\sum_{K=1}^{2} \mathrm{MIN}[\mu D_k(d), \mu T_k(t), \mu MI(m), \mu B_k(b), \mu NDVI_k(v)](u_k)}{\sum_{k=1}^{2} \mathrm{MIN}[\mu D_k(d), \mu T_k(t), \mu MI(m), \mu B_k(b), \mu NDVI_k(v)]}$$

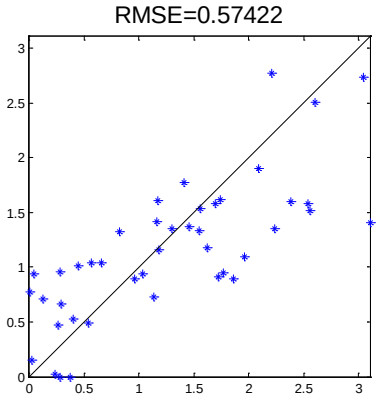
A quantitative remote sensing monitoring model of snail is established based on T-S fuzzy, solving the linear expression of nonlinear relationship between snails and environmental factors.

Snail-transmitted disease-Schistosomiasis(Dongting Lake)

Validation-Predict the density and distribution of snails at Junshan, Dongting Lake :



Accuracy of snail distribution:95.12%



Comparison of field measured data (x-axis) and predicted data(y-axis)

Predict snail distribution and density of 2008 based on the T-S Fuzzy RS model by only using environmental parameters retrieved from RS data

Snail-transmitted disease-Schistosomiasis (Xinmin Beach,Gaoyou Lake)

Case study area: Xinmin Beach,Gaoyou Lake

- *Compare the environment characteristics of Xinmin beach, Gaoyou Lake with Junshan, Dongting Lake*

	P: Junshan, Dongting Lake	C: Xinmin Beach, Gaoyou Lake
Types of distribution	Lake type	Lake type
Influence of water distribution	Winter Land, Summer Water	Floodplains
Time of medication	Spring and Autumn	Spring and Autumn
LST	suitable breeding	suitable breeding
Elevation	20-35m	1-7m

Similar

Difference

- **The environment of Xinmin Beach is basically consistent with Junshan, except for the elevation.**
- **Need to build a new suitability index membership function of elevation to improve the T-S Fuzzy RS monitoring model built by the data of Junshan, Dongting Lake.**

Snail-transmitted disease-Schistosomiasis (Xinmin Beach,Gaoyou Lake)

EO Data acquisition

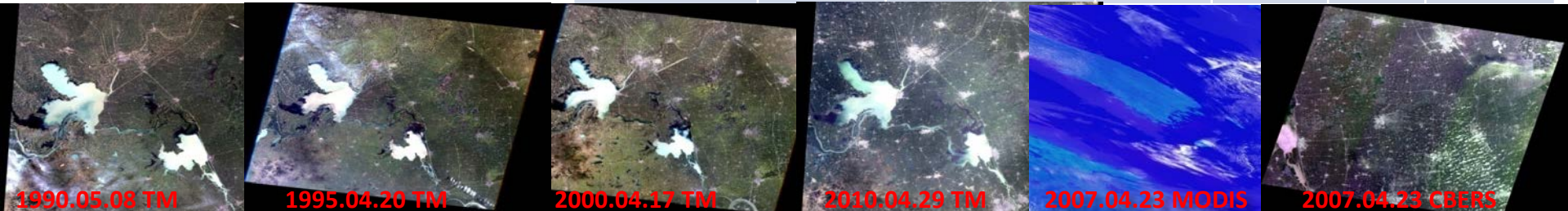
- **Landsat can provide long-term RS data for environment factor retrieval, but lack of data around April 2005,2006,2007.**
  - **CBERS 02B and MODIS data are used instead, according to the similar bandwidth as shown in Table 2.**
  - **Normalization of temporal-spatial-spectral-angle features of different remotely sensed data**

Table1. RS data (20 years)

ID	Acquisition time	Satellite	Sensor
1	1990.05.08	Lansat5	TM
2	1995.04.20	Lansat5	TM
3	2000.04.17	Lansat5	TM
4	2007.04.23	CBERS 02B, TERRA	CCD（band1~4） MODIS（band6,7）
5	2010.04.29	Lansat5	TM

Table2. Bandwidth of CBERS-2's CCD, MODIS band 6,7 and LANDSAT-TM5

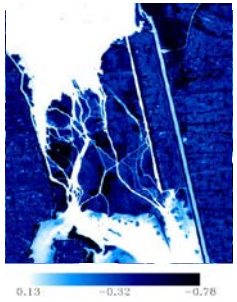
	Band1	Band2	Band3	Band4	Band5	Band7	Resolution
Landsat TM5	0.45-0.52	0.52-0.6	0.63-0.69	0.76-0.9	1.55-1.75	2.08-2.35	30m
CBERS CCD	0.45-0.52	0.52-0.59	0.63-0.69	0.77-0.9			20m
MODIS					1.628-1.65	2.105-2.135	500m



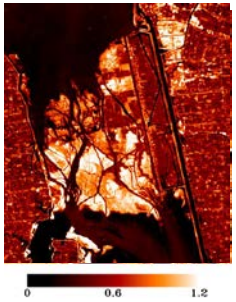
Snail-transmitted disease-Schistosomiasis (Xinmin Beach,Gaoyou Lake)

Environmental parameters retrieval from RS data

NDVI(Normalized Difference Vegetation Index)



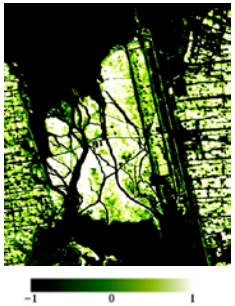
Tasseled cap transformation _Wetness



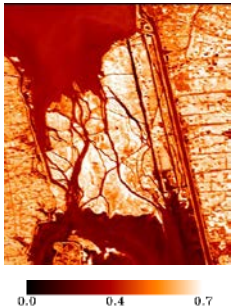
Tasseled cap transformation _Brightness

NDMI(Normalized difference moisture index

From Landsat TM (1990.05.08)

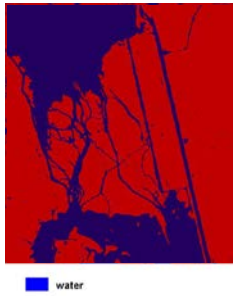


NDVI



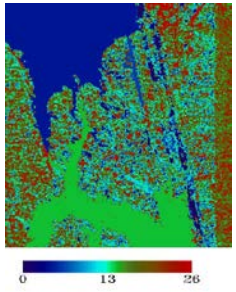
Tasseled cap transformation _Brightness

From CBERS and MODIS (2017.04.03)



Water distribution

From NDMI

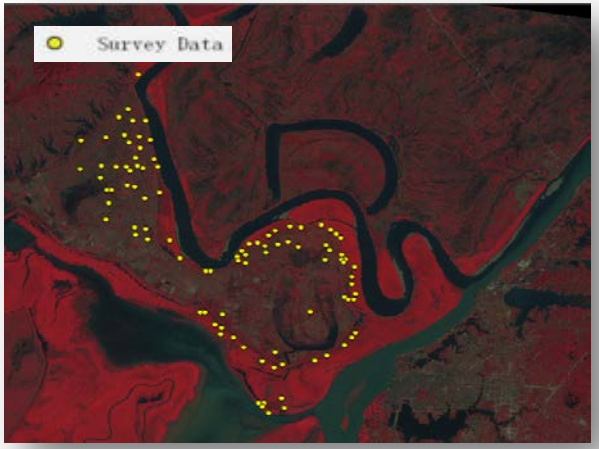


DEM

From ASTER

Snail-transmitted disease-Schistosomiasis (Xinmin Beach,Gaoyou Lake)

In-situ data measurements



(a) Junshan, Donging Lake

(b) Xinmin beach, Gaoyou lake

- Snail field data of Xinmin 1990-2010
- Survey parameters:
  - ✓ Survey block
  - ✓ Survey block area
  - ✓ Snail area within block
  - ✓ No. of survey frame
  - ✓ No. of living snails within a frame (area of a frame is 0.11m^2)

Fig.3 Distribution of snail

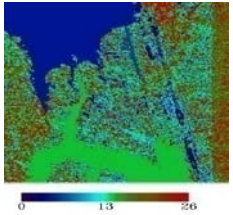
The field data of Junshan, Dongting Lake are collected by GPS. In fact, China CDC have huge field data in the unit of village block. In this study the predicted results are validated by block survey data.

Snail-transmitted disease-Schistosomiasis (Xinmin Beach,Gaoyou Lake)

Suitability index for snail breeding of RS environmental parameters

Gaoyou Lake data

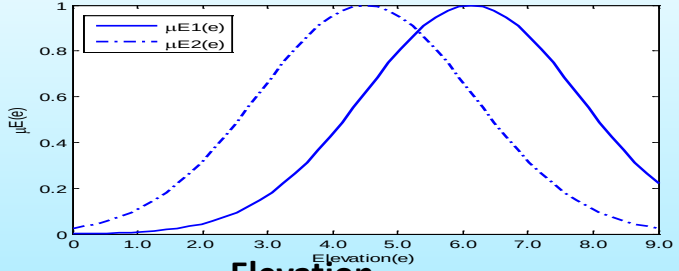
Survey data



DEM data

T-S Fuzzy

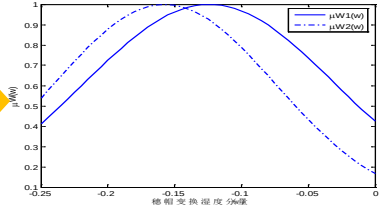
Suitability index for snail breeding



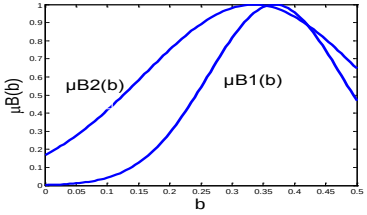
Elevation

Membership functions of Elevation
(Snail thrive when elevation between 4-6m)

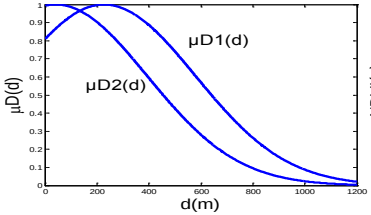
Dongting Lake data



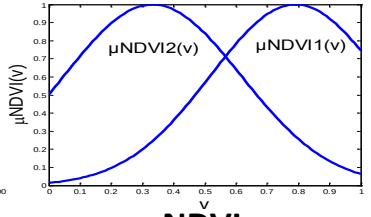
TC_Wetness



TC_Brightnes



Distance from water



NDVI

Snail-transmitted disease-Schistosomiasis (Xinmin Beach,Gaoyou Lake)

Research results

1990-2010 dynamic monitoring results of snail spatial distribution

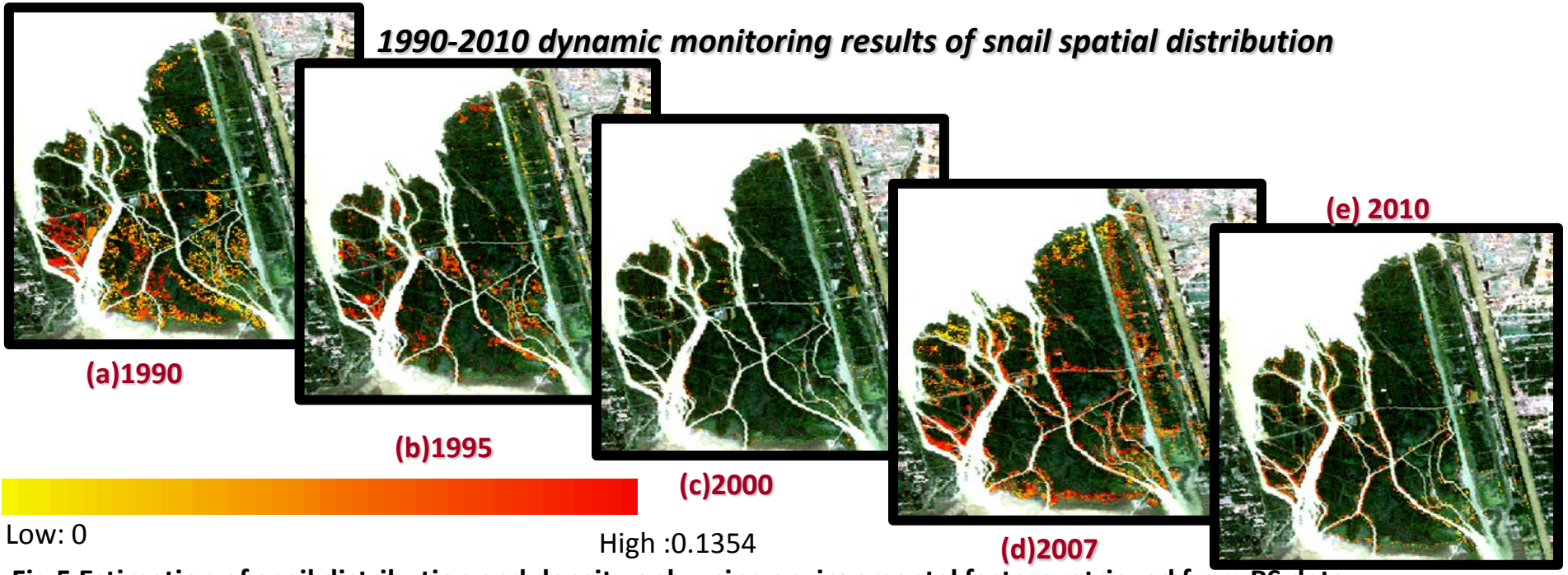


Fig.5 Estimation of snail distribution and density only using environmental factors retrieved from RS data

Snail-transmitted disease-Schistosomiasis (Xinmin Beach,Gaoyou Lake)

■ Validation

Compare the predicted results with survey data (block by block)

Right predict
Wrong predict
No survey data

(a)1990 (b) 1995 (c)2000 (d)2007 (e)2010

Fig. 6 Predicted results of the snail distribution blocks

Table.3 Accuracy of predicted snail distribution blocks

Year	No. of survey snail block	No. of predict snail block	Accuracy
1990	73	64	87.67%
1995	33	30	91%
2000	15	15	100%
2007	40	37	92.5%
2010	59	52	88.14%
Average			92%

Current Research Progress

2、*Mosquito-borne disease*——Malaria

Case study area: Tengchong

Coordinates	25.017°N, 98.483°E
Province	Yunnan, China
Area	5,845 km^2 (2,257 sq mi)
Average Elevation	1,667 m (5,469 ft)
Population	620,000
Borders with Myanmar	in the northwest for 151 km.

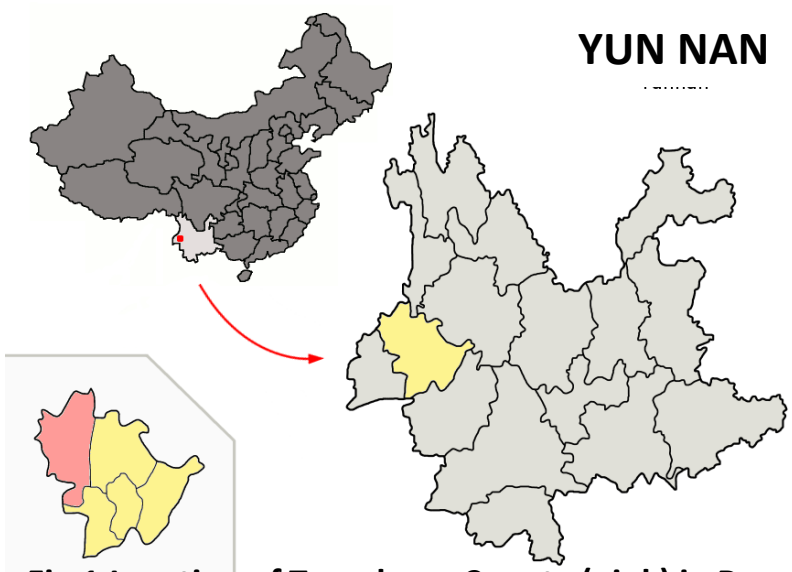


Fig.1 Location of Tengchong County (pink) in Baoshan City, Yunnan province

Mosquito-borne disease——Malaria

Biologic characteristics

Malaria is found mainly relating to climatic and environmental factors, such as temperature, humidity, vegetation, etc. where

- **mosquitoes can survive and multiply**

Environmental factors	Characteristics
Temperature	Below 16℃ or above 30℃, it will grow slowly and die
EAT(Effective accumulated temperature)	At least 220℃ •day to grow up to adult mosquito, survival percentage increased with ETA
Humidity of air	Suitable range is 60%~85%, too low or too high can not survival
Vegetation	Cover the sunshine, adjust humidity

Whether the RS technology and T-S fuzzy can describe the biologic characteristics between mosquito and environmental factors like above snail ? And find the quantitative suitability relationship?

Mosquito-borne disease——Malaria

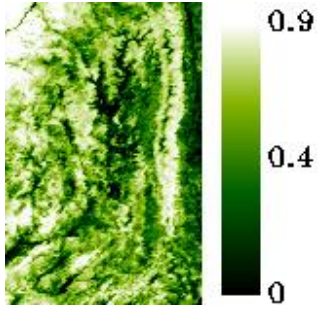
EO Data acquisition

ID	Environmental parameters	Sensor	Satellite	Spatial resolution	Temporal resolution	Temporal coverage
1	Surface soil moisture	AMSR-E	Aqua	25km	Daily	2003-2011
2	Surface temperature and NDVI	MODIS	Terra	1KM	Monthly And Daily	2002-2014
3	NDVI, pool and gutter	TM/ EMT+	Lansat5/7	30m	Yearly (Jan,Feb,Mar,Dec)	2002-2013
4	DEM	ASTER	Terra	30m	N/A	N/A

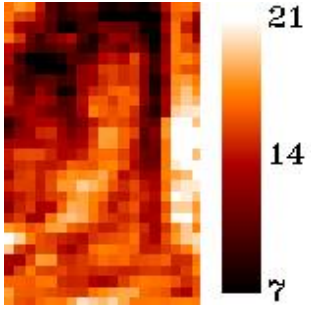
During the rainy season, it is hard to get high spatial and temporal resolution Vis-NIR RS data, which would limit the precision of the research.

Mosquito-borne disease——Malaria

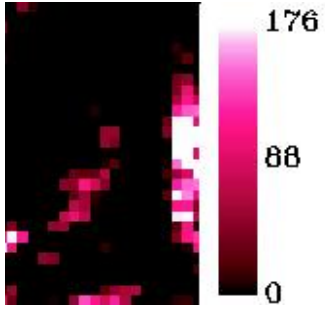
Environmental parameters retrieval from RS data



NDVI(Normalized Difference Vegetation Index)

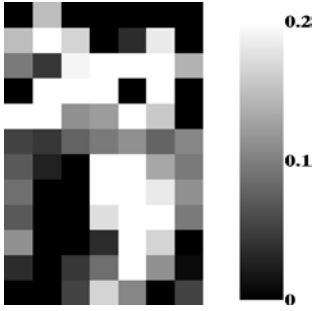


LST (Land Surface Temperature)



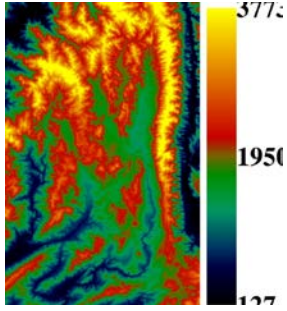
EAT(Effective accumulated temperature)

From MODIS (2005.01)



Surface soil moisture

From AMSR-E



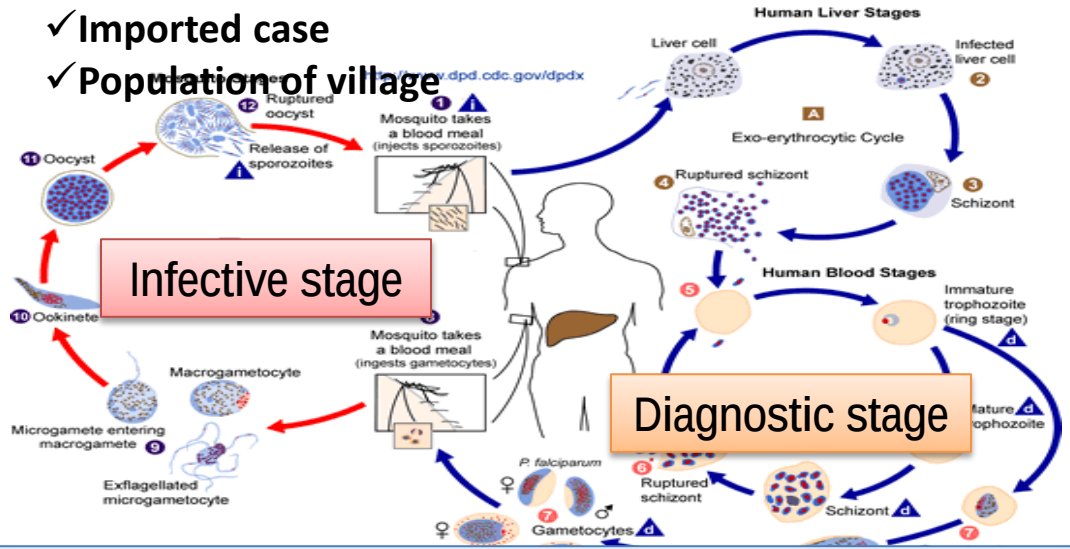
DEM

From ASTER

Mosquito-borne disease——Malaria

Problem of In-situ data: no mosquito data

- Monthly malaria case data between 2002 to 2014 were collected from 18 village in Tengchong:
  - ✓Indigenous case
  - ✓Imported case
  - ✓Population of village



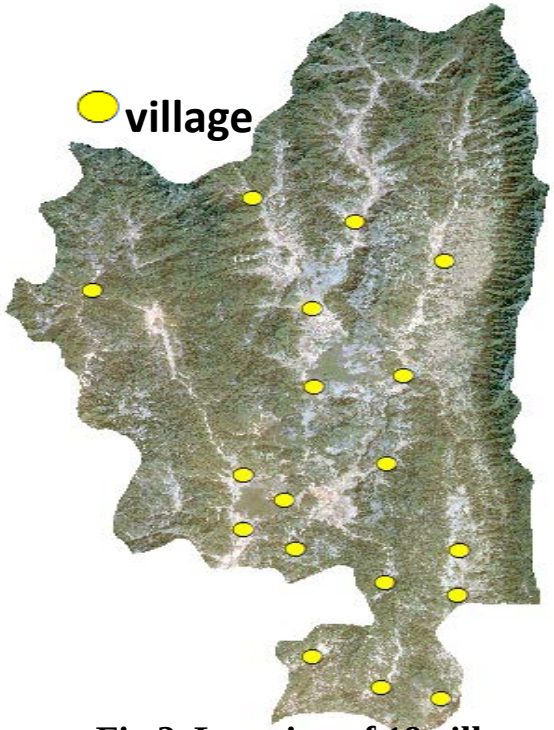


Fig.2 Location of 18 villages

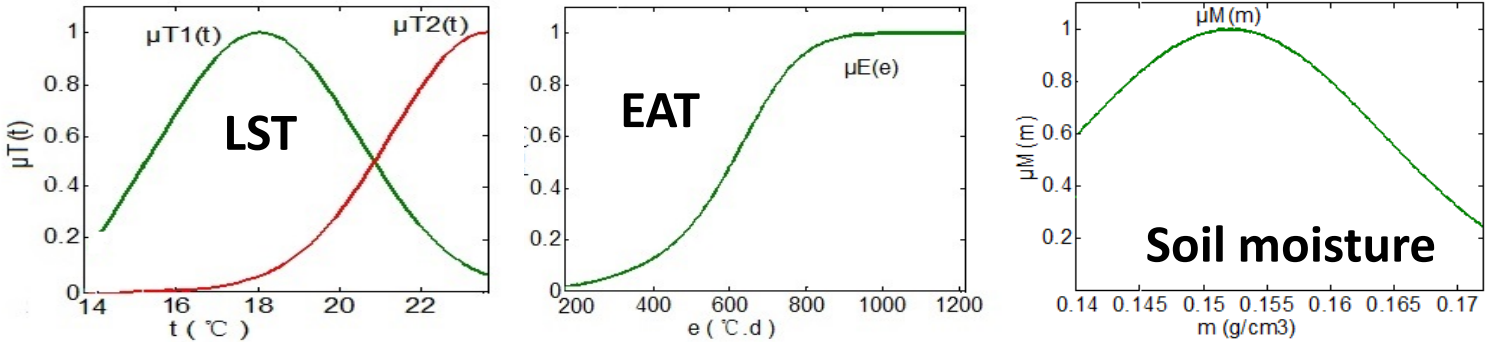
It is about one month delay from infecting by mosquitoes to discover malaria. So the malaria cases data can be used to validate predicted results of previous monthly RS data

Mosquito-borne disease——Malaria

Research results

Quantitative suitability relationship between mosquito and RS environmental parameters:

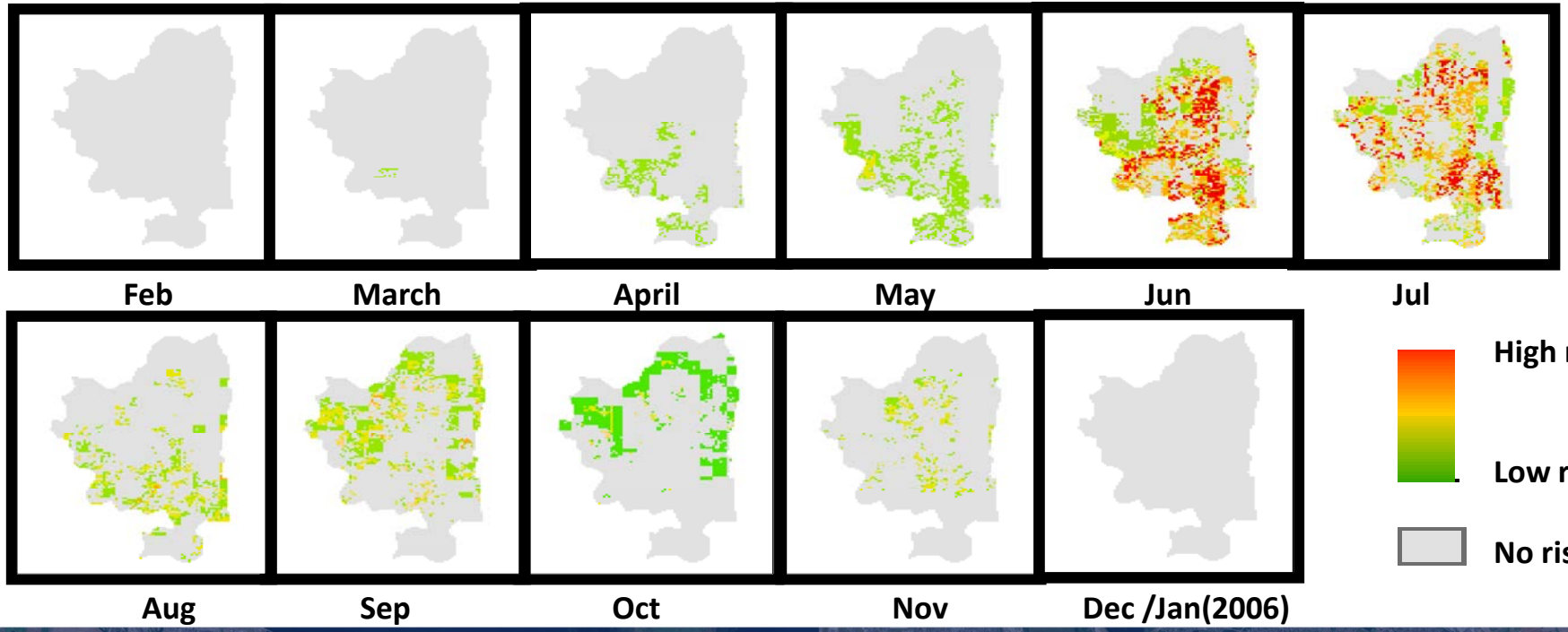
Suitability index for malaria



- Growth and breeding rate of mosquito and Malaria parasites are influenced by temperature:
  - Red line: below 16℃, the mosquito die, and suitability index increases with temperature between 16℃ to 23℃.
  - Green line: above 14℃, the malaria parasites can complete their growth cycle, and the peak is between 17℃ to 20℃.
- When it reaches the threshold of Effective Accumulated Temperature(EAT)-about 200℃ •day to grow up to adult mosquito, percentage of survival increases with ETA, and the peak is at 800 ℃•day.
- Soil moisture can affect the humidity of air, too low or too high are not conductive to mosquito survival.

Mosquito-borne disease——Malaria

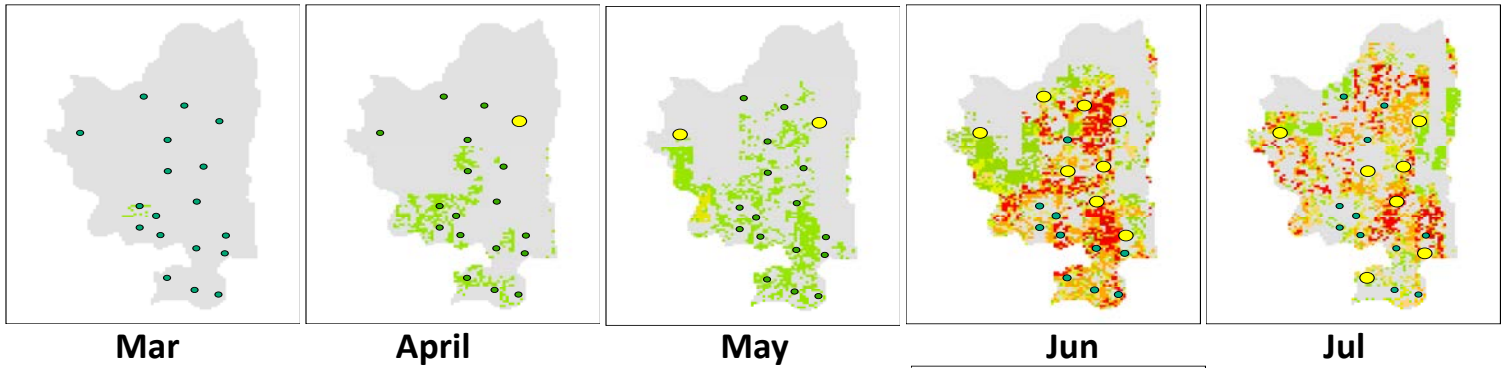
12 months' dynamic monitoring results of malaria risk at Tengchong

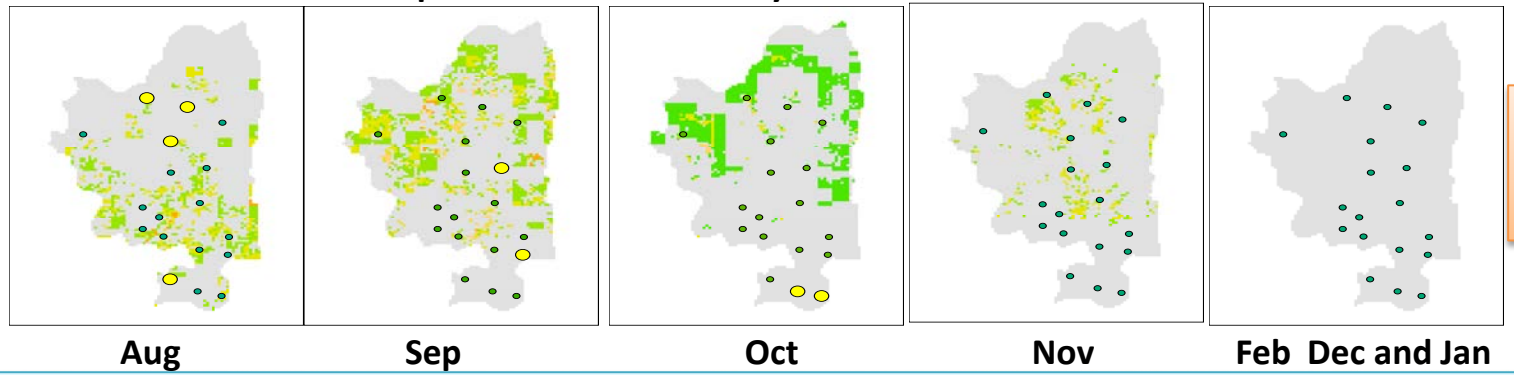


Mosquito-borne diseases——Malaria

Validation

Compare the predicted results with survey data (by village location)





No Indigenous malaria case

Indigenous Malaria case

Accuracy of predicted malaria incident location is 74% .

The location prediction accuracy is rather good when only using 1km and 25km spatial resolution RS data. Higher spatial resolution should improve the results.

Summary

DEVELOP a quantitative remote sensing monitoring model of snail (vector of schistosomiasis) by using the TS (Takagi-Sugeno) fuzzy information theory. Good results in predicting the distribution and density of snails at Junshan, Dongting Lake.

IMPROVE the TS Fuzzy RS snail monitoring model, in order to be applied to different places, different time series, and different RS data. Take 20 years (1990-2010) dynamic monitoring of Gaoyou Lake to further validate its effectiveness.

NEW DEVELOP the T-S fuzzy remote sensing monitoring and prediction model in malaria by using the malaria case data and the associated RS environmental data. The average accuracy of predicted malaria incident location is 74%.

DEMONSTRATE that combine RS technology with data mining(T-S fuzzy) can play an important role in predicting vector-borne diseases.

PROBLEM: lack of RS data, inconsistent from multi-source RS data, difference of field survey data, Long-term dynamic monitoring(Large scale, high resolution) , model improvement… …

Future works

Model Improvement

- Use more high spatial and temporal resolution RS data , Such as Sentinel-2 MSI , Landsat 8,GF,ZY, CBERS-04,HJ-1A/B/C, etc.
- Comparison and Analysis the performances of different EO data in vector-borne disease RS monitoring application.

Model Application

- Long-term dynamic monitoring of the risk of malaria and Schistosomiasis, which will provide technology support for the control and prevention of malaria and Schistosomiasis in China.


Thank you for
your attentions.