GRDSS: Development and Applications

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AGENDA

- FOSS


GRASS GIS - The World Leading Free Software GIS - Mozilla Firefox

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http://wgbis.ces.iisc.ernet.in/grass/index.php

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GRASS in the Press

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FOSS4G 2009, Sydney

GRASS Book

OSGeo Project

Welcome to GRASS GIS

You are at an official GRASS site (other mirror sites)
This site is updated daily: 13 Nov 2009

Home	Intro	Docs	Download	Community	Applications	Development

Celebrating 25 years!

GRASS User map (without pop-up)

Geographic Resources Analysis Support System

Commonly referred to as GRASS, this is free Geographic Information System (GIS) software used for geospatial data management and analysis, image processing, graphics/maps production, spatial modeling, and visualization. GRASS is currently used in academic and commercial settings around the world, as well as by many governmental agencies and environmental consulting companies. GRASS is an official project of the Open Source Geospatial Foundation.

Module of the day:
v.support Updates vector map metadata.

Latest News! XML RSS FEED

- 18 Sep 2009: **GRASS 6.4.0 module synopsis published** - A list of all modules with GUI menu locations
- 11 Jun 2009: **GRASS 6.4.0 RC5 released** - Fifth release candidate of stable release 6.4.0 which includes the new graphical user interface, native MS-Windows support new functionality and bugfixes
- 03 Jun 2009: **New WinGrass 6.4.0RCsvn stand-alone package** - Please help test!
- 29 Apr 2009: **OSGeo welcomes 20 Google Summer of Code students** - Including 3 GRASS projects

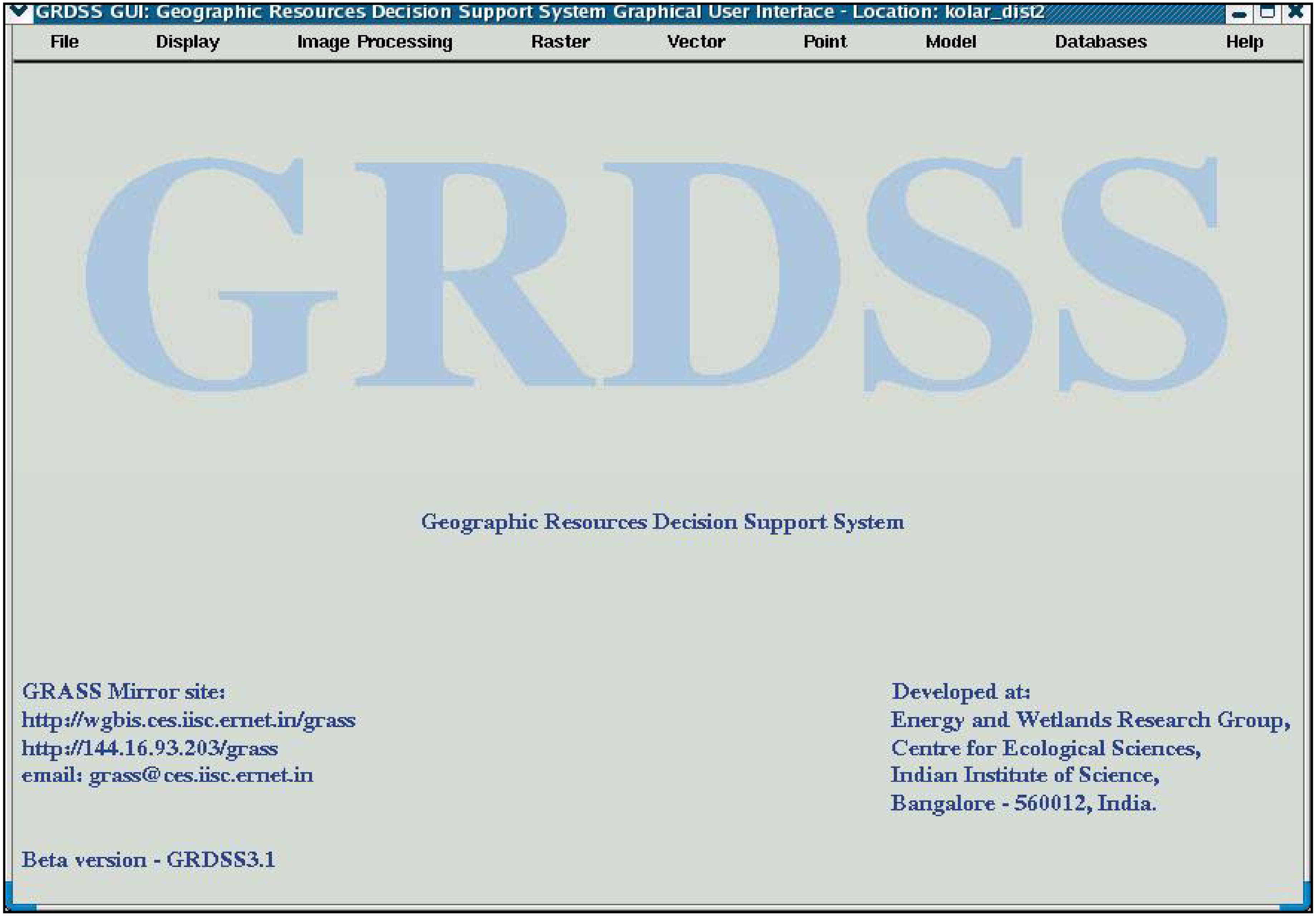
Upcoming GRASS/FOSS4G related events: XML RSS FEED

- **Geoinformatics FCE CTU 2009 - Free and Open Source Software in Geoinformatics** - 17-18 Sep 2009, Prague, Czech Republic
- **FOSS4G 2009 in Sydney - Free and Open Source Software for Geospatial** - 20-23 Oct 2009, Sydney, Australia

Done

GRDSS: Journey in 2003

GRDSS in 2004



FOSS KIOSK

Welcome to Free & Open Source Software (FOSS) at CES, IISc, Bangalore, India

- Home
- GRASS Mirror site in India
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- Open Source Database
- Open Content Management System
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- Useful Softwares
- List of Free Software
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- FOSS by OSGeo-India
- FOSS Foundation
- FOSS Group
- Contact Us
- Energy Research Group
- Centre for Ecological Sciences
- Indian Institute of Science
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Visitors: 21265

Home

E-mail

Geographic Resources Analysis Support System

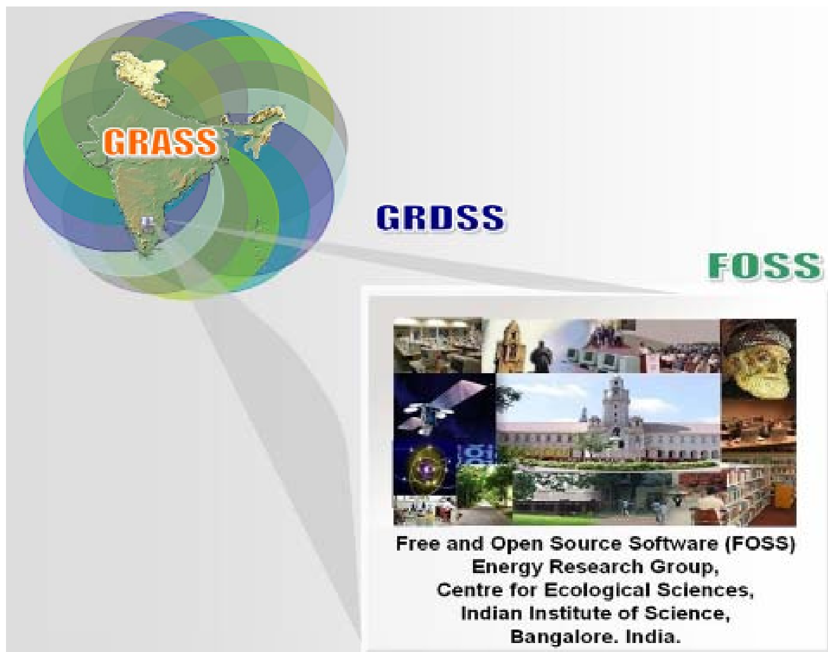
Geographic Resources Decision Support System

GEOVISUALISATION OF CHERUVANNUR VILLAGE PANCHAYAT, KOZHIKODE, KERALA, INDIA

NEW

Open Source GIS in India, Discussion Meeting, 16th November 2009, CiSTUP, IISc

NEW

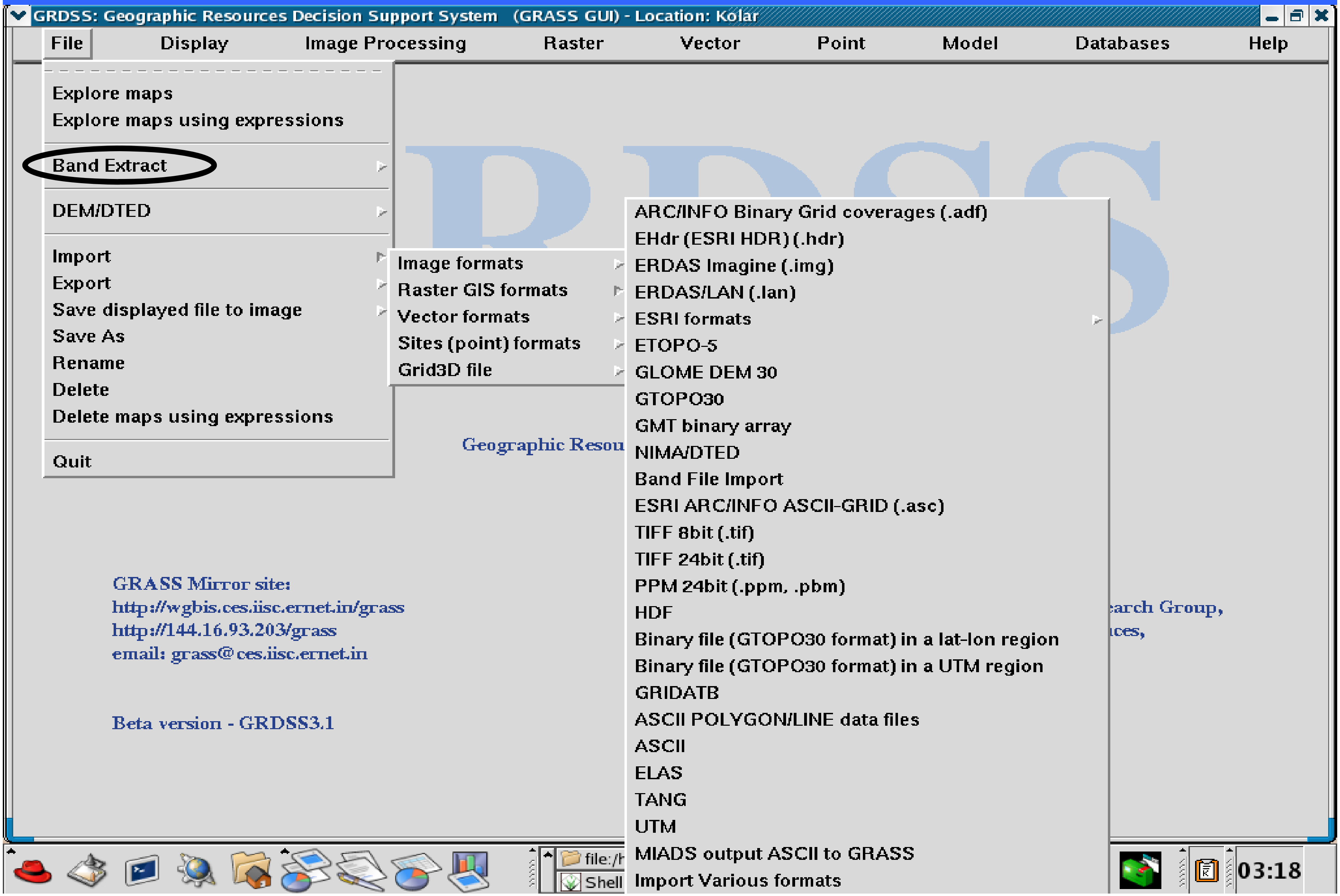


Good Evening! The time is 7:07 pm (IST). Thursday, 12 November, 2009.
Best viewed under Browsers: Firefox 2.0+, IE 7 at 800 x 600 and above.
Web designed by Uttam, Energy Research Group, CES, IISc.

Development

- FOSS website
- Band extraction modules in GRDSS – LISS III and PAN
- Image fusion modules – HIS, Brovey, High Pass Filter, High Pass Modulation, Principal Component Analysis, Fourier Transform, Atrous, MRAIM, Gram Schmidt, CN Spectral, Luminance Chrominance
- Forest fragmentation module – Patch, Transitional, Edge, Perforated, Interior
- Urban fragmentation module – Developed, Non-developed, Water, Infill, Expansion, Outlying growth

GRDSS: LISS III and PAN band extraction



NRSA information Help

NRSA (National Remote Sensing Agency)

NRSA (National Remote Sensing Agency) at Hyderabad is a Department of Space sponsered organisation, that is engaged in carrying out satellite and airborne remote sensing activities including aerial photography, digital photogrammetry, and microwave remote sensing, etc. The main objective of NRSA is the acquisition, processing and dissemination of Remote Sensing data.

Indian Remote Sensing Satellites

Indian Remote Sensing Satellites (IRS-1A, IRS-1B, IRS-1C and IRS-1D) has strengthened the scope of Remote Sensing capabilities of India. IRS-1C and IRS-1D data is received at the earth station of NRSA, Hyderabad and then supplied to users on request. IRS-1C has three cameras: (1) a Panchromatic camera
(2) a Linear Imaging Self-Scanning Sensor - III (LISS-III)
(3) a Wide Field Sensor (Wifs)

DATA REQUEST FROM NRSA

Data from Integrated Information Management System (IIMS) at NRSA Data Centre (NDC) provide services to the users of the satellite images. NRSA data request can be made in three ways:

1. Digital browse facility - LISS-III and PAN images are generated and compressed after acquisition and transferred to NDC (NRSA Data Centre) in optical jukebox. Based on user input, the requested data is retrieved from the jukebox, decompressed and displayed with the Digital browsing facility.

2. Referencing scheme maps- Reference scheme maps are generated with path/row and scene centre marked on a baseline map to assist users in identifying the area of interest. The referencing scheme map for IRS-1C is provided to users in three different types:

   1.) for India and neighbouring countries on 1 : 6,000,000 scale,
   2.) six zones of India, viz. Central, North, South, East, West and Andaman and Nicobar on 1 : 4,500,000 scale and
   3.) the entire coverage of Hyderabad earth station.

3. Orbital Calendar - Orbital Calendar, giving the datails of paths covered on different days, is useful to users to plan their procurement of satellite data products. It is possible to know, on which day the required data have been collected ao are going to be collected.

Typical IRS-1C orbital calender

Day	Path number														
1	1	318	294	270	246	222	198	174	150	126	102	78	54	30	
2	6	323	299	275	251	227	203	178	155	131	107	83	59	35	
3	11	328	304	280	255	232	208	184	160	136	112	88	64	40	
4	16	333	309	285	261	237	213	189	165	141	117	93	69	45	
5	21	338	314	285	266	242	218	194	170	146	122	98	74	50	26
6	2	319	295	290	247	223	199	175	151	127	103	99	55	31	
7	7	324	300	271	252	228	204	180	156	132	108	84	60	36	
8	12	329	305	276	257	233	209	185	161	137	113	89	65	41	
9	17	334	310	281	262	238	214	180	156	132	108	84	60	36	
10	22	339	315	285	267	243	219	195	171	147	123	99	75	51	27
11	3	320	296	291	248	224	200	176	152	128	104	80	56	32	
12	8	325	301	272	253	229	205	181	157	133	109	85	61	37	
13	13	330	306	282	258	234	210	186	162	138	114	90	66	42	
14	18	335	311	287	263	239	215	191	167	143	119	95	71	47	
15	23	340	316	292	268	244	220	196	172	148	124	100	76	52	28
16	4	321	297	273	249	225	201	177	153	129	105	81	57	33	
17	9	326	302	278	254	230	206	182	158	134	110	86	62	38	
18	14	331	307	283	259	235	211	187	163	139	115	91	67	43	
19	19	336	312	288	264	240	216	192	168	144	120	96	72	48	24
20	24	341	317	293	269	245	221	197	173	149	125	101	77	53	29
21	5	322	298	274	250	226	202	178	154	130	106	82	58	34	
22	10	327	303	279	255	231	207	183	159	135	111	87	63	39	
23	15	332	308	284	260	236	212	188	164	140	116	92	68	44	
24	20	337	313	289	265	241	217	193	169	145	121	97	73	49	25
25	1	318	294	270	246	222	198	174	150	126	102	78	54	30	

Indian users send their request details like area of interest, date/period of interest and sensor. The requests are studied and prioritized, depending upon the various factors. NDC (NRSA Data Centre) then sends the acquisition plan to Spacecraft Control Centre(SCC), where the necessary plans are worked out and after a successful acquisition of a pass, a scene is processed according to the user's requirements and delivered to the user.

For more information log on to: http://www.nrsa.gov.in
Postal address: National Remote Sensing Agency,
(Dept. of Space), Govt. of India),
Balanagar, Hyderabad-500037.
India.

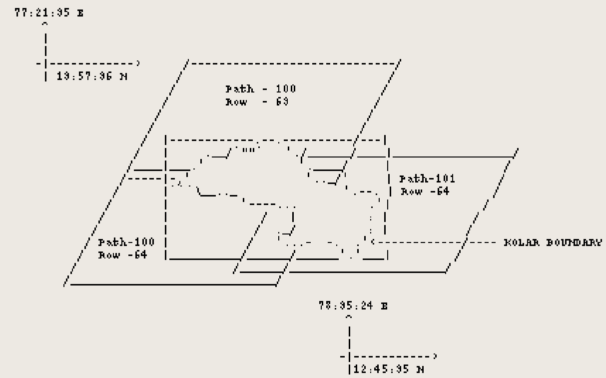
OK

NRSA information Help

57 H - 13
57 K - 1,2,3,4,6,7,8,11,12
57 L - 1,5

Data Required:

Date	Satellite id	Sensor	Path	Row
04-JAN-2004	1D	LIS 3	100	63
04-JAN-2004	1D	LIS 3	100	64
01-JAN-2004	1D	LIS 3	101	64



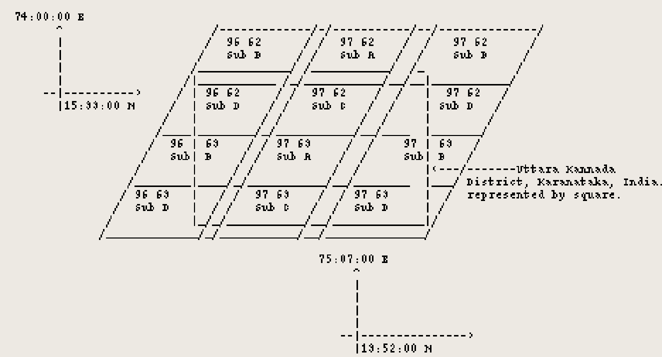
Let us take another example,
Suppose we need to buy scenes for Uttara Kannada District, Karnataka.

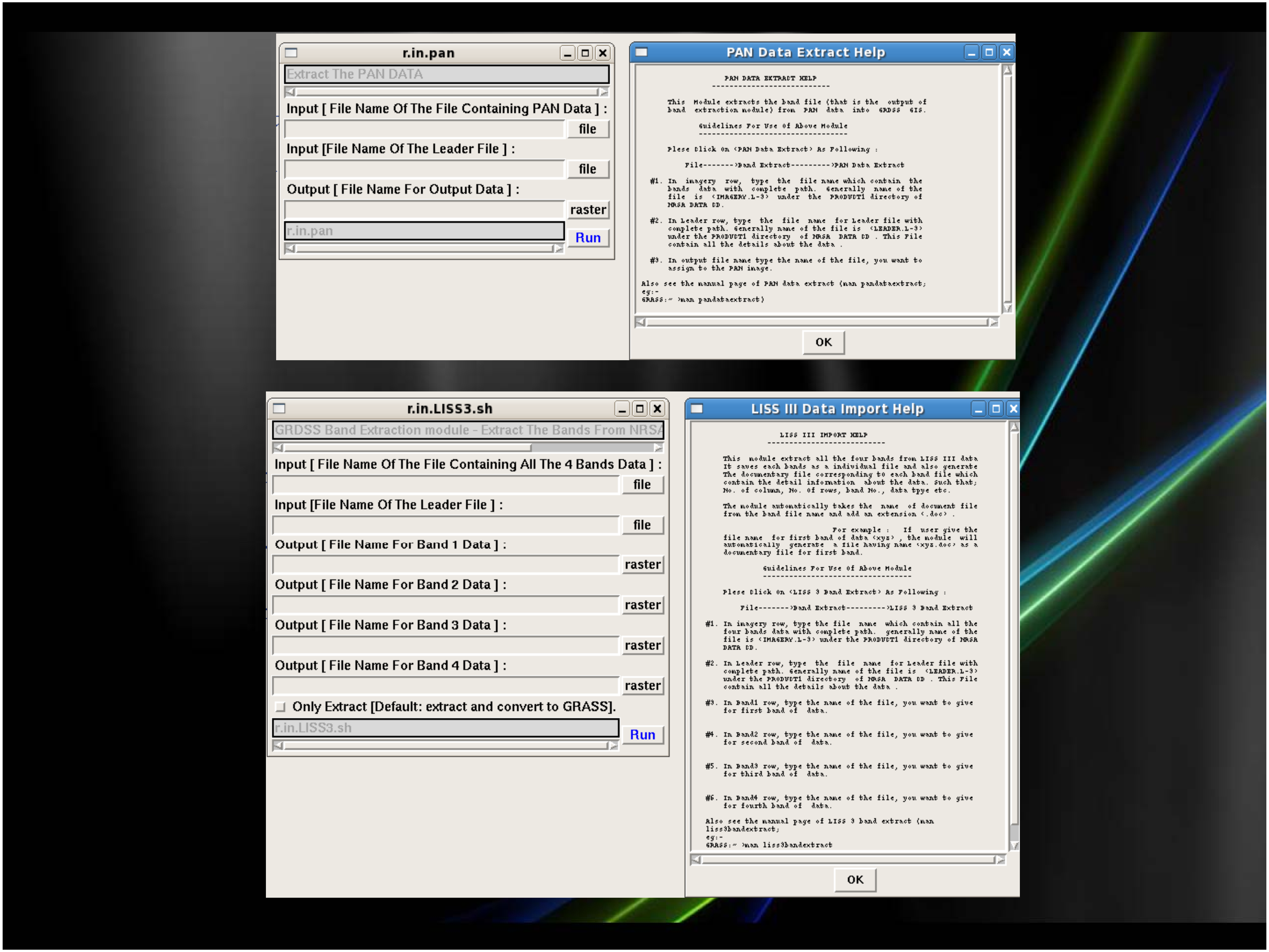
The toposheet numbers we require are:
(scale - 1:250,000) - 48 I, 48 J, 48 K, 48 M, 48 N
(scale - 1:50,000) - 48 I - 6,7,8,11,12,15,16
48 J - 1,2,5,6,7,8,9,10,11,12,13,14,15,16
48 K - 9
48 M - 4
48 N - 1,2,3

Data Required:

Panchromatic Data:

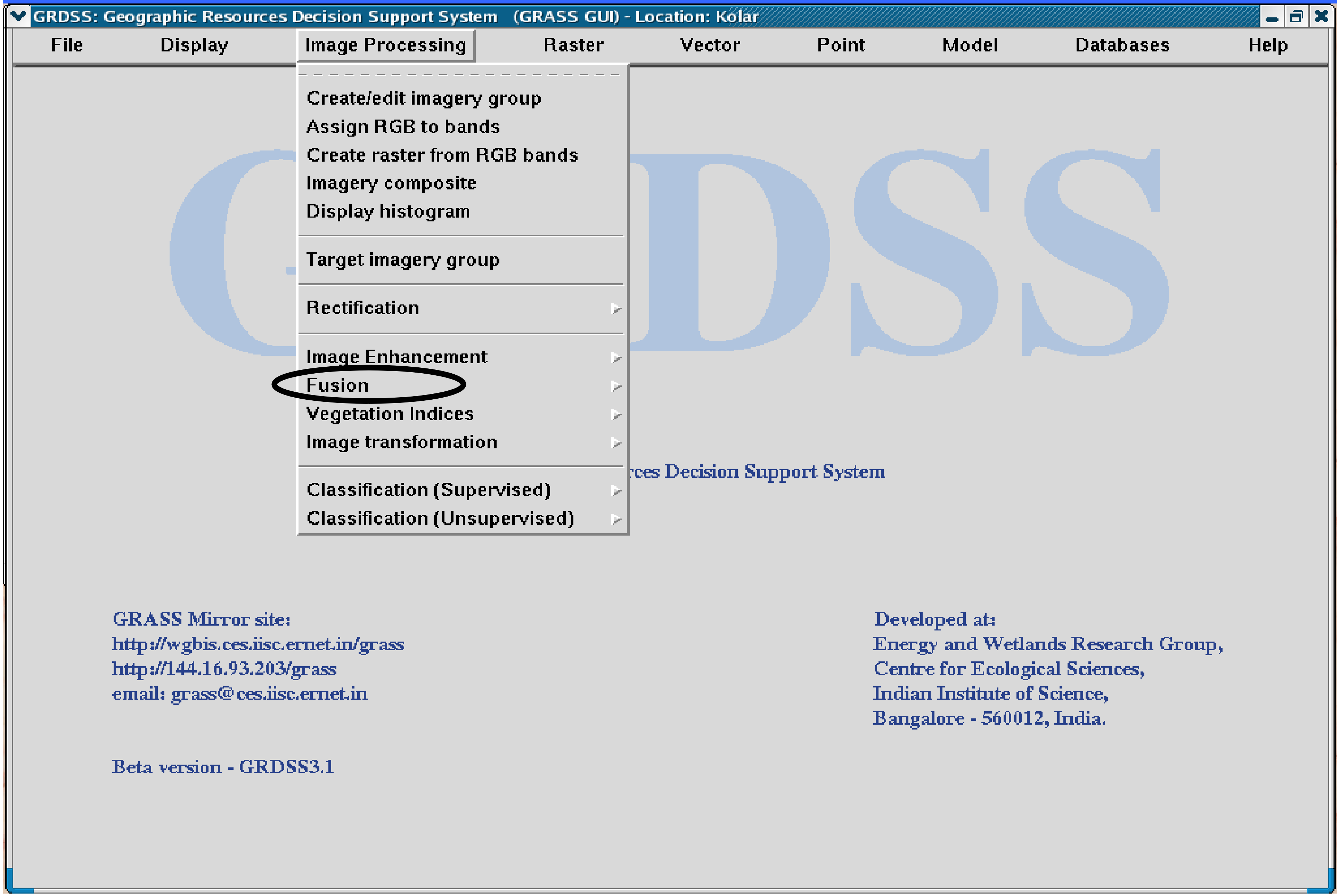
Date	Satellite id	Sensor	Path	Row	Sub-scene
17-OCT-2003	1C	PAN	96	62	B
17-OCT-2003	1C	PAN	96	62	D
17-OCT-2003	1C	PAN	96	63	B
17-OCT-2003	1C	PAN	96	63	D
28-OCT-2003	1C	PAN	97	62	C
04-OCT-2003	1C	PAN	97	62	D
04-OCT-2003	1C	PAN	97	63	B
28-OCT-2003	1C	PAN	97	63	C
04-OCT-2003	1C	PAN	97	63	D





r.in.pan
Extract The PAN DATA
Input [File Name Of The File Containing PAN Data] :
file
Input [File Name Of The Leader File] :
file
Output [File Name For Output Data] :
raster
r.in.pan
Run
PAN Data Extract Help
PAN DATA EXTRACT HELP
This Module extracts the band file (that is the output of band extraction module) from PAN data into GRDSS GIS.
Guidelines For Use Of Above Module
Plese Click On <PAN Data Extract> As Following :
File------->Band Extract--------->PAN Data Extract
#1. In imagery row, type the file name which contain the bands data with complete path. Generally name of the file is <IMAGERY.L-3> under the PRODUCT1 directory of NRSA DATA CD.
#2. In Leader row, type the file name for Leader file with complete path. Generally name of the file is <LEADER.L-3> under the PRODUCT1 directory of NRSA DATA CD . This File contain all the details about the data .
#3. In output file name type the name of the file, you want to assign to the PAN image.
Also see the manual page of PAN data extract (man pandataextract;
eg:-
GRASS:~ >man pandataextract)
OK
r.in.LISS3.sh
GRDSS Band Extraction module - Extract The Bands From NRSA
Input [File Name Of The File Containing All The 4 Bands Data] :
file
Input [File Name Of The Leader File] :
file
Output [File Name For Band 1 Data] :
raster
Output [File Name For Band 2 Data] :
raster
Output [File Name For Band 3 Data] :
raster
Output [File Name For Band 4 Data] :
raster
Only Extract [Default: extract and convert to GRASS].
r.in.LISS3.sh
Run
LISS III Data Import Help
LISS III IMPORT HELP
This module extract all the four bands from LISS III data It saves each bands as a individual file and also generate The documentary file corresponding t0 each band file which contain the detail information about the data. Such that; No. of column, No. 0f rows, band No., data tpye etc.
The module automatically takes the name of document file from the band file name and add an extension <.doc> .
For example : If user give the file name for first band of data <xyz> , the module will automatically generate a file having name <xyz.doc> as a documentary file for first band.
Guidelines For Use Of Above Module
Plese Click On <LISS 3 Band Extract> As Following :
File------->Band Extract--------->LISS 3 Band Extract
#1. In imagery row, type the file name which contain all the four bands data with complete path. generally name of the file is <IMAGERY.L-3> under the PRODUCT1 directory of NRSA DATA CD.
#2. In Leader row, type the file name for Leader file with complete path. Generally name of the file is <LEADER.L-3> under the PRODUCT1 directory of NRSA DATA CD . This File contain all the details about the data .
#3. In Band1 row, type the name of the file, you want to give for first band of data.
#4. In Band2 row, type the name of the file, you want to give for second band of data.
#5. In Band3 row, type the name of the file, you want to give for third band of data.
#6. In Band4 row, type the name of the file, you want to give for fourth band of data.
Also see the manual page of LISS 3 band extract (man liss3bandextract;
eg:-
GRASS:~ >man liss3bandextract
OK

GRDSS: Image Fusion



RGB-HIS Fusion

- RGB bands are transformed to HIS (Carper et al., 1990)

(hue – dominant or average wavelength of light contributing to a colour,
intensity – total brightness of the colour,
saturation – purity of colour relative to gray)

$$\begin{pmatrix} DN^{l}_{PAN} \\ V_1 \\ V_2 \end{pmatrix} = \begin{pmatrix} \frac{1}{3} & \frac{1}{3} & \frac{1}{3} \\ \frac{-1}{\sqrt{6}} & \frac{-1}{\sqrt{6}} & \frac{2}{\sqrt{6}} \\ \frac{1}{\sqrt{6}} & \frac{-1}{\sqrt{6}} & 0 \end{pmatrix} \begin{pmatrix} DN^{l}_{MS1} \\ DN^{l}_{MS2} \\ DN^{l}_{MS3} \end{pmatrix}$$

where DN^{l}_{MS1}, DN^{l}_{MS2}, DN^{l}_{MS3} are the low resolution bands

V_1, V_2 are the intermediate variables.

Carper, W. J., Lillesand, T. M., and Kieffer, R. W., 1990, The use of Intensity-Hue-Saturation transformations for merging SPOT Panchromatic and multispectral image data. *Photogrammetric Engineering and Remote Sensing, 56, 459-467.*

RGB-HIS Fusion

$$I = DN^{l}_{PAN} \qquad H = \tan^{-1}\left(\frac{V_2}{V_1}\right) \qquad S = \sqrt{V_1^2 + V_2^2}$$

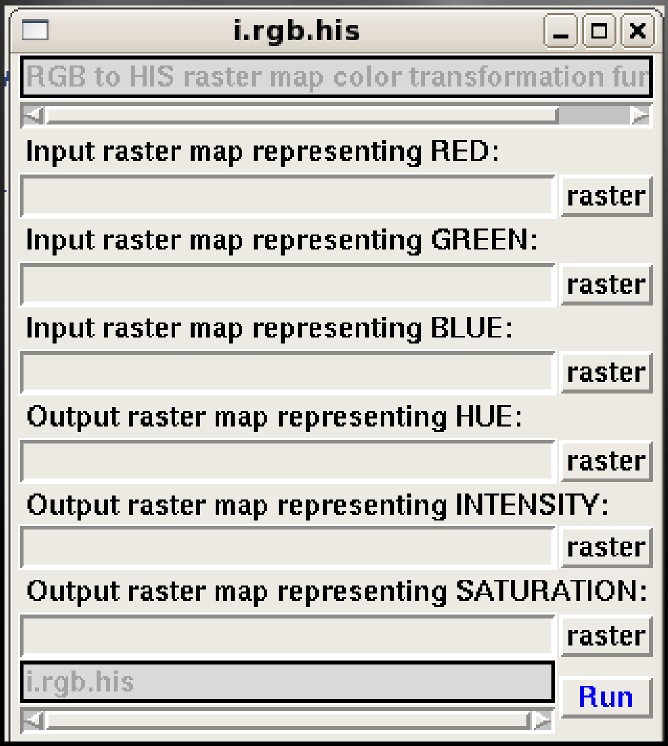
- *I is replaced with high spatial resolution image – $DN^{h'}_{PAN}$ (contrast stretched to I) which is to be integrated.*

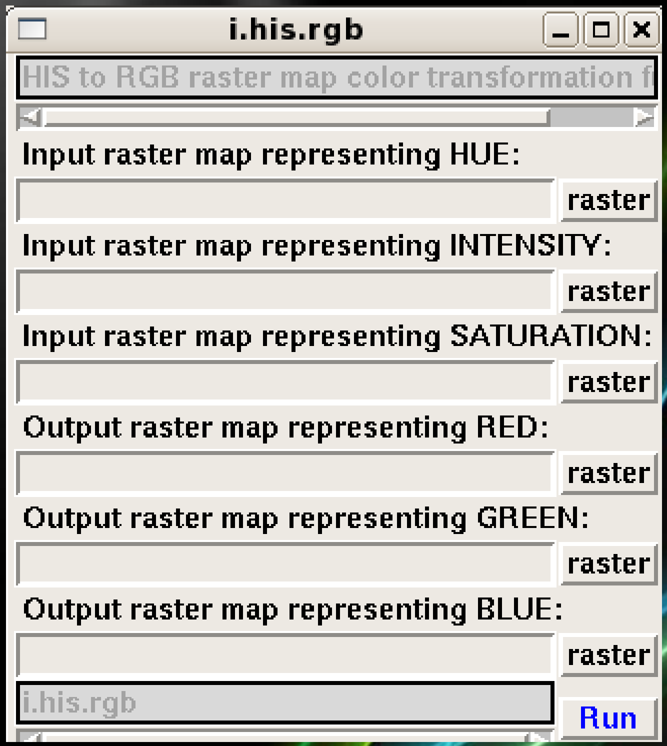
$$DN_{new\_image} = \frac{\sigma_{ref}}{\sigma_{old}}(DN_{old} - \mu_{old}) + \mu_{ref}$$

$$\begin{pmatrix} DN^{h}_{MS1} \\ DN^{h}_{MS2} \\ DN^{h}_{MS3} \end{pmatrix} = \begin{pmatrix} 1 & \frac{-1}{\sqrt{6}} & \frac{3}{\sqrt{6}} \\ 1 & \frac{-1}{\sqrt{6}} & \frac{-3}{\sqrt{6}} \\ 1 & \frac{2}{\sqrt{6}} & 0 \end{pmatrix} \begin{pmatrix} DN^{h'}_{PAN} \\ V_1 \\ V_2 \end{pmatrix}$$

where DN^{h}_{MS1}, DN^{h}_{MS2}, DN^{h}_{MS3} are the fused high resolution multispectral bands.

RGB-HIS Fusion





Brovey Fusion

(Pohl, 1996)

$$\begin{pmatrix} DN^h_{MS1} \\ DN^h_{MS2} \\ DN^h_{MS3} \end{pmatrix} = \begin{pmatrix} DN^l_{MS1} \\ DN^l_{MS2} \\ DN^l_{MS3} \end{pmatrix} + \left(DN^h_{PAN} - DN^l_{PAN}\right) \begin{bmatrix} \dfrac{DN^l_{MS1}}{DN^l_{PAN}} \\ \dfrac{DN^l_{MS2}}{DN^l_{PAN}} \\ \dfrac{DN^l_{MS3}}{DN^l_{PAN}} \end{bmatrix}$$

where

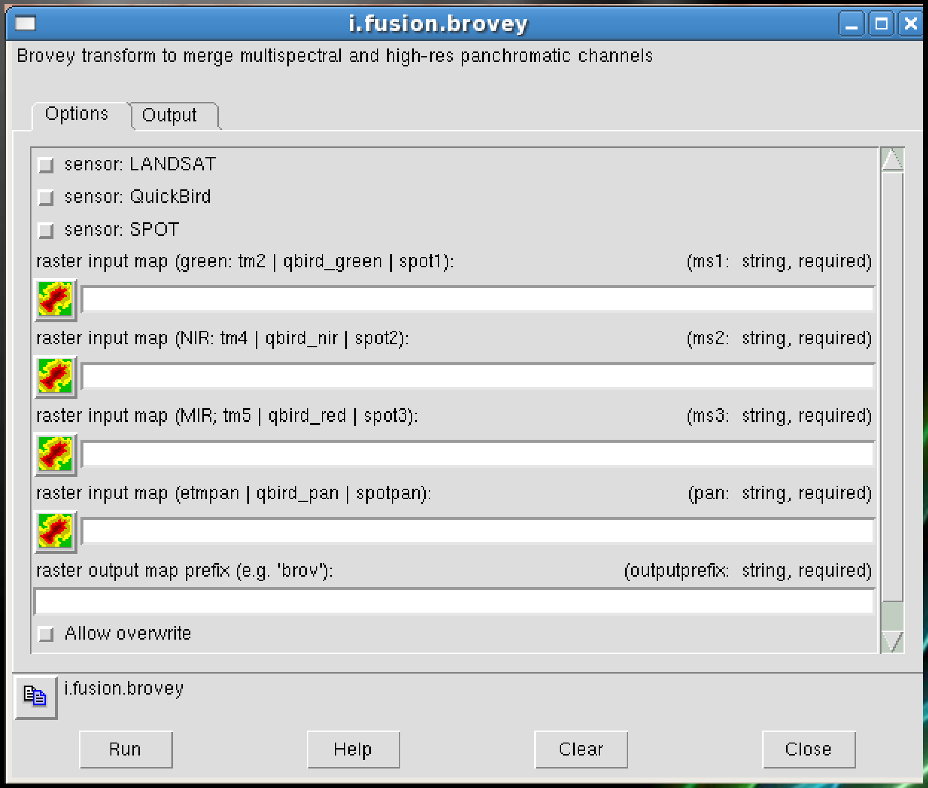
$$DN^l_{PAN} = (1/3)(DN^l_{MS1} + DN^l_{MS2} + DN^l_{MS3})$$

DN^l_{MS1}, DN^l_{MS2}, DN^l_{MS3} are the low resolution bands

DN^h_{MS1}, DN^h_{MS2}, DN^h_{MS3} are the fused high resolution multispectral bands

Pohl, C., 1996, Geometric aspects of multisensor image fusion for topographic map updating in the humid Tropics. *ITC publication No. 39 (Enschede: ITC), ISBN 90 6164 121 7.*

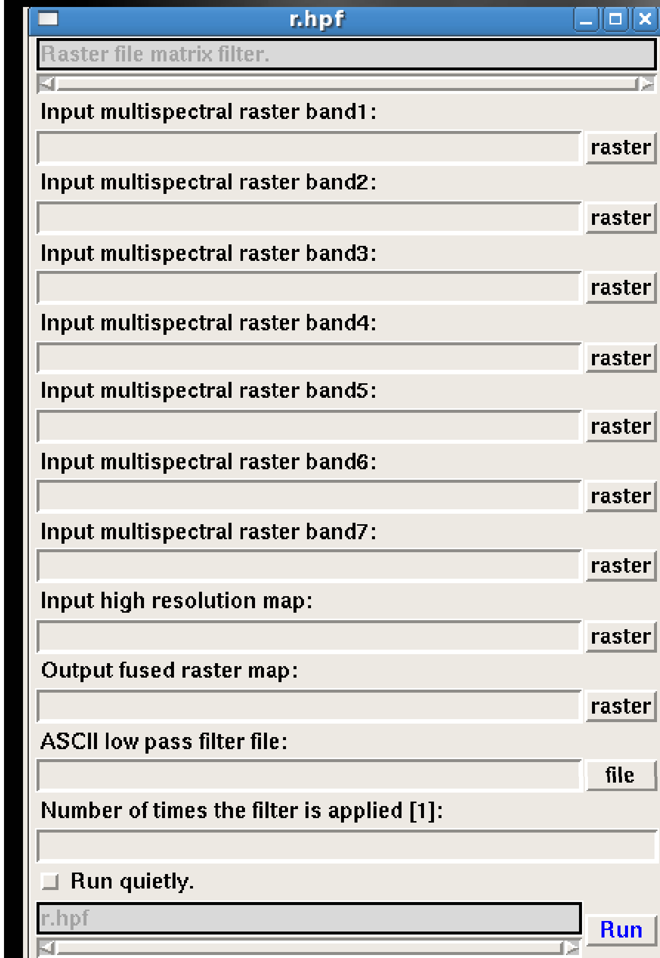
Brovey Fusion

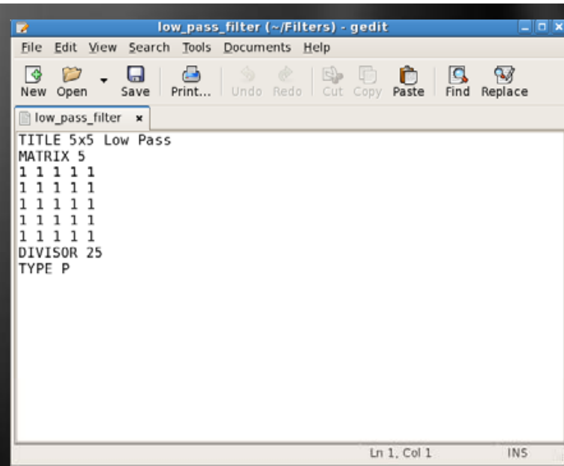


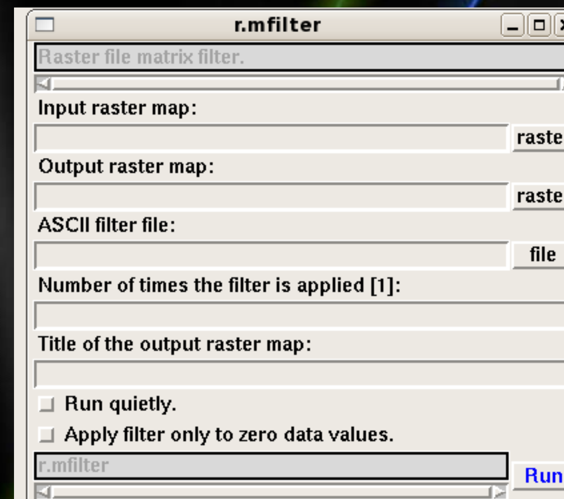
High Pass Filter Fusion

$$DN^h_{MSS} = DN^l_{MS} + (DN^h_{PAN} - DN^l_{PAN})$$

where $DN^l_{PAN} = DN^h_{PAN} * h_0$ and h_0 is a LP filter (average or smoothing filter).



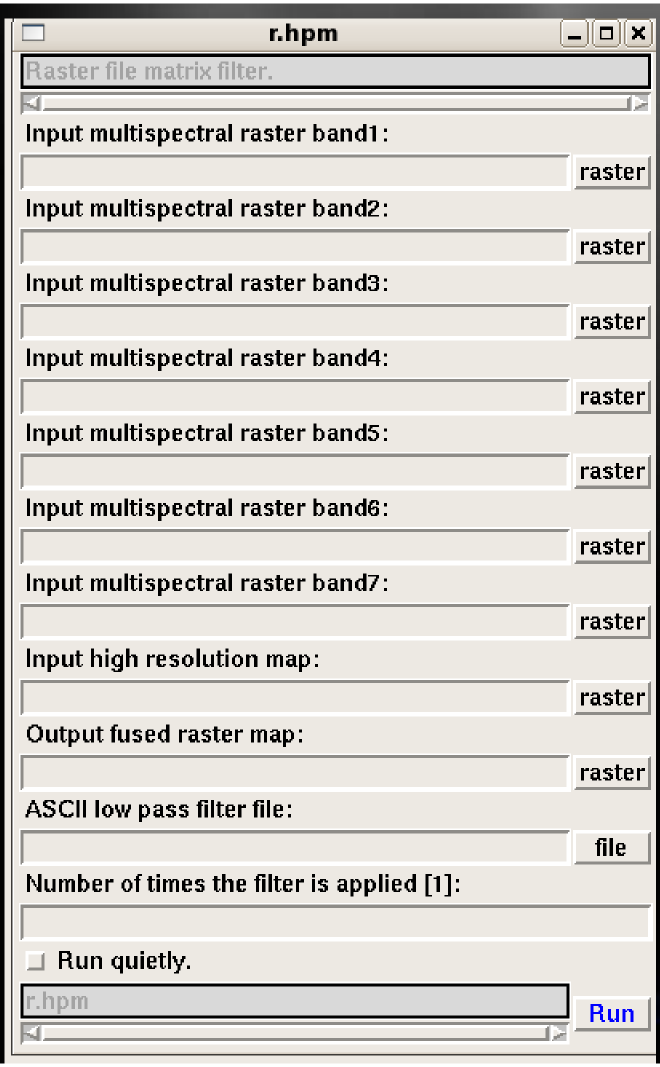


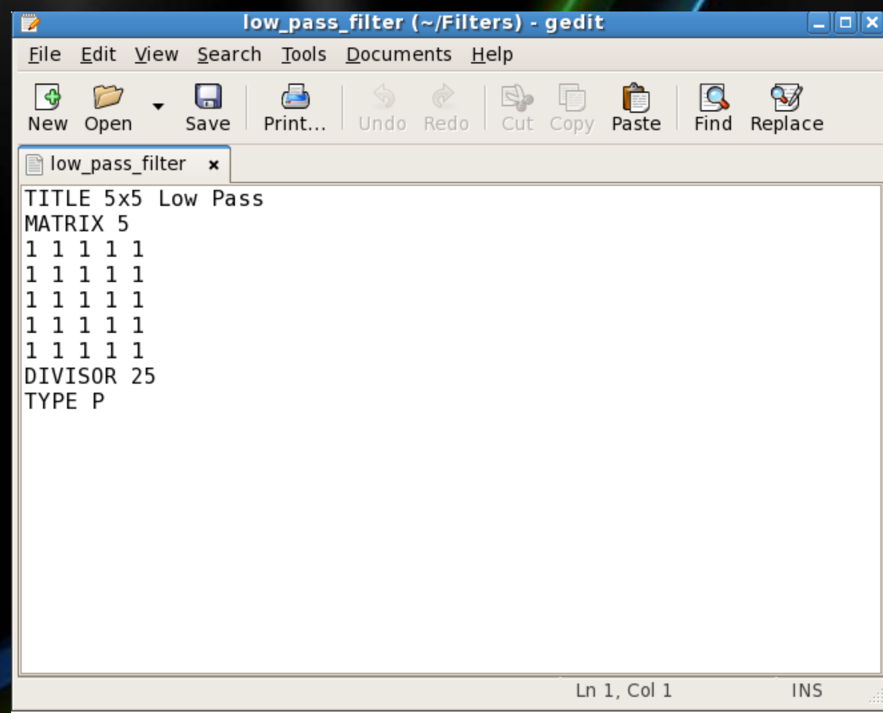


High Pass Modulation Fusion

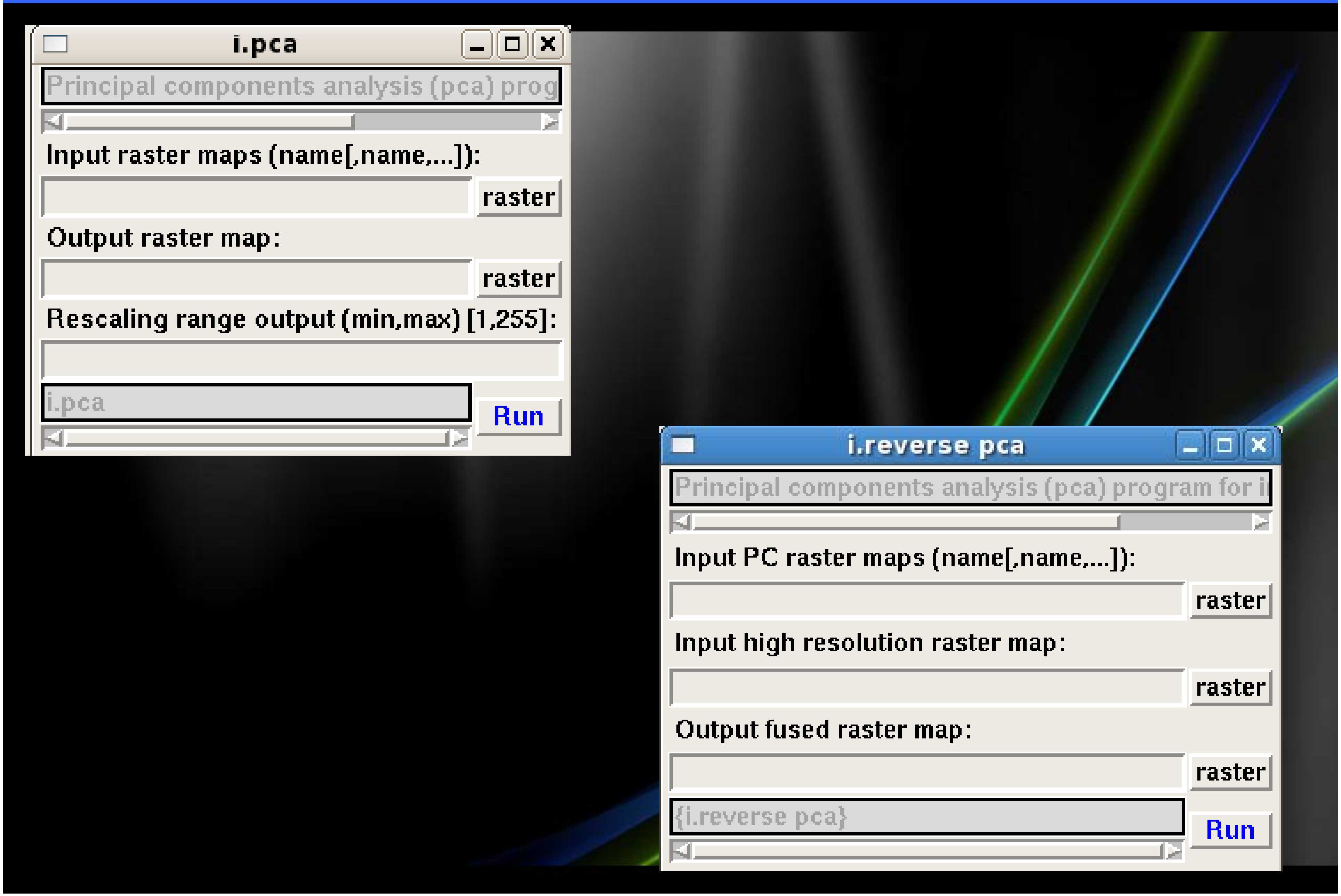
$$DN^{h}_{MS} = DN^{l}_{MS} + (DN^{h}_{PAN} - DN^{l}_{PAN})\frac{DN^{l}_{MS}}{DN^{l}_{PAN}}$$

where $DN^{l}_{PAN} = DN^{h}_{PAN} * h_0$ and h_0 is the same LP filter as used in the HPF method.



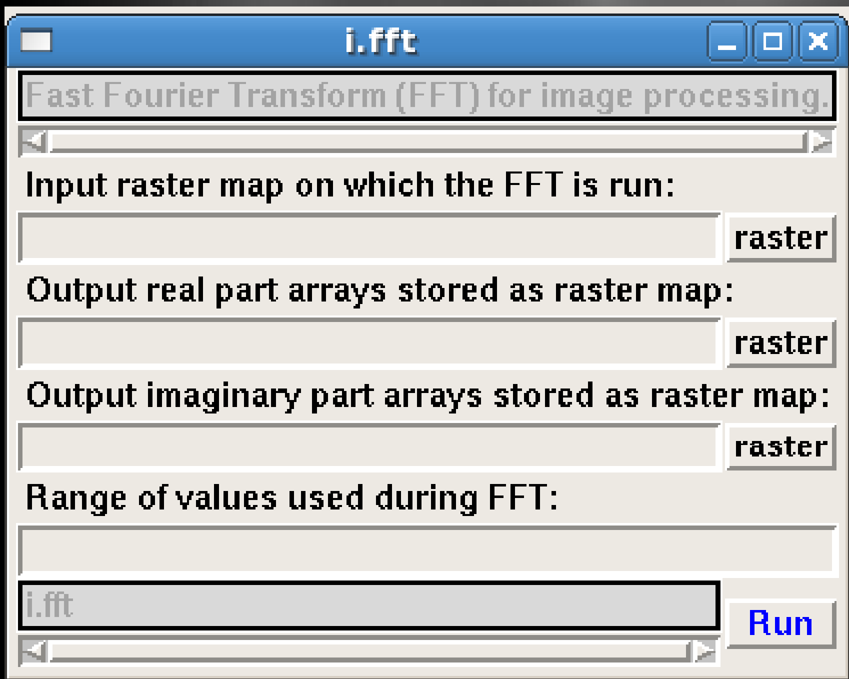


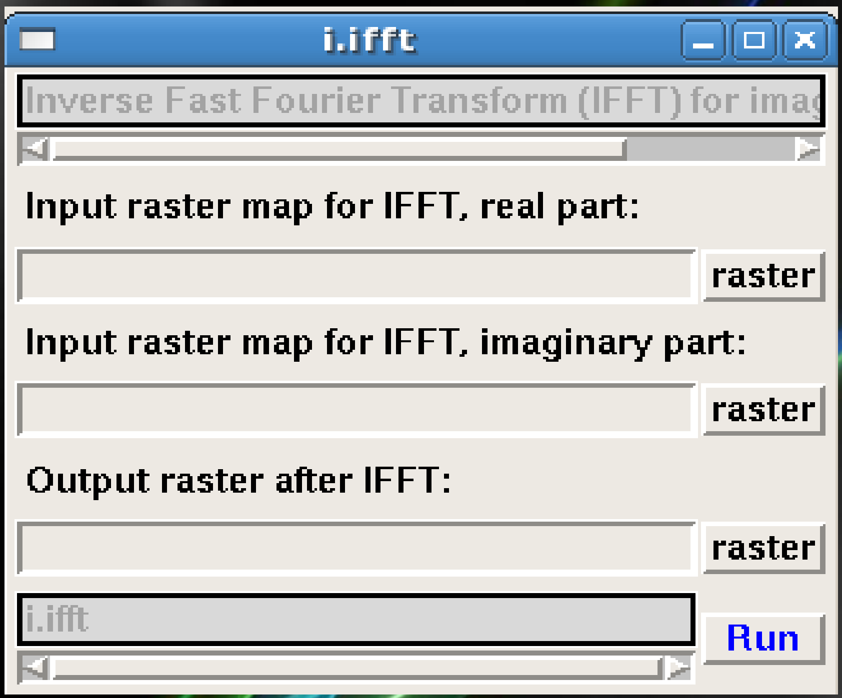
PCA Fusion


i.pca
Principal components analysis (pca) prog
Input raster maps (name[,name,...]):
raster
Output raster map:
raster
Rescaling range output (min,max) [1,255]:
i.pca
Run
i.reverse pca
Principal components analysis (pca) program for i
Input PC raster maps (name[,name,...]):
raster
Input high resolution raster map:
raster
Output fused raster map:
raster
{i.reverse pca}
Run

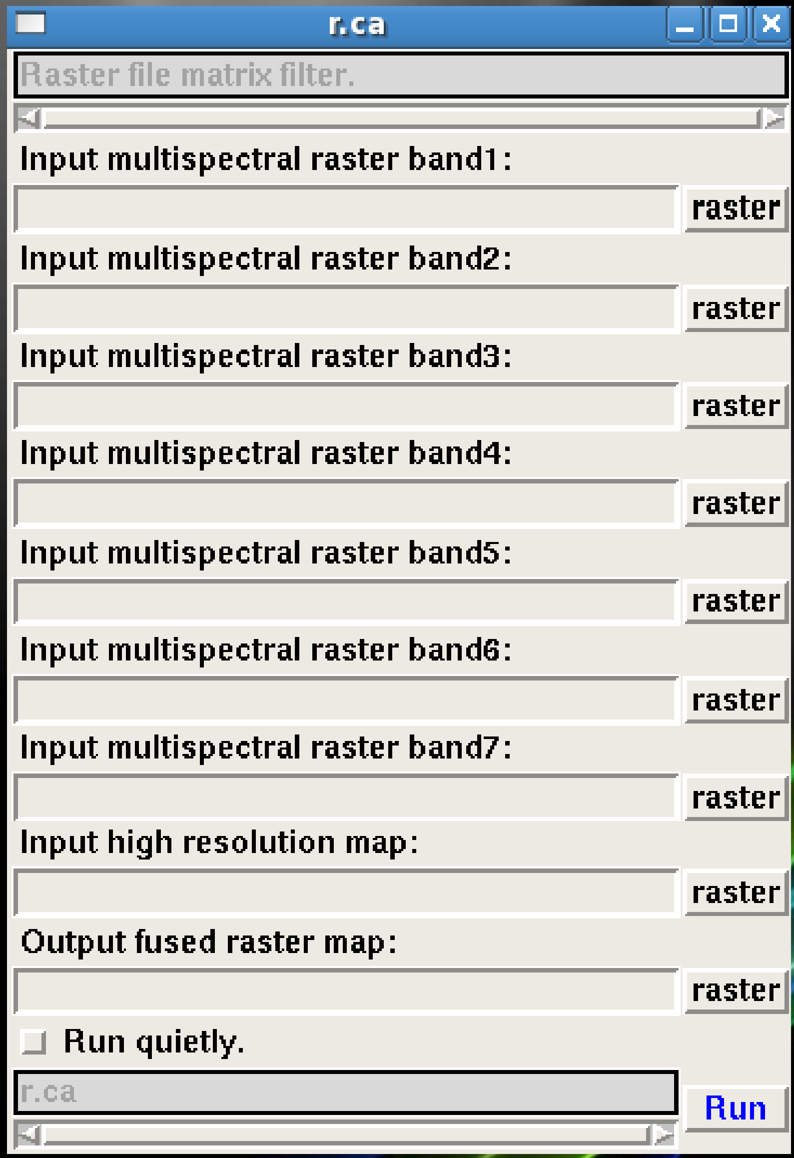
Fourier Transformation Fusion

$$MS_i^H = FT^{-1}\{LPF\{FT(MS_i^L)\} + HPF\{FT(PAN)\}\}$$

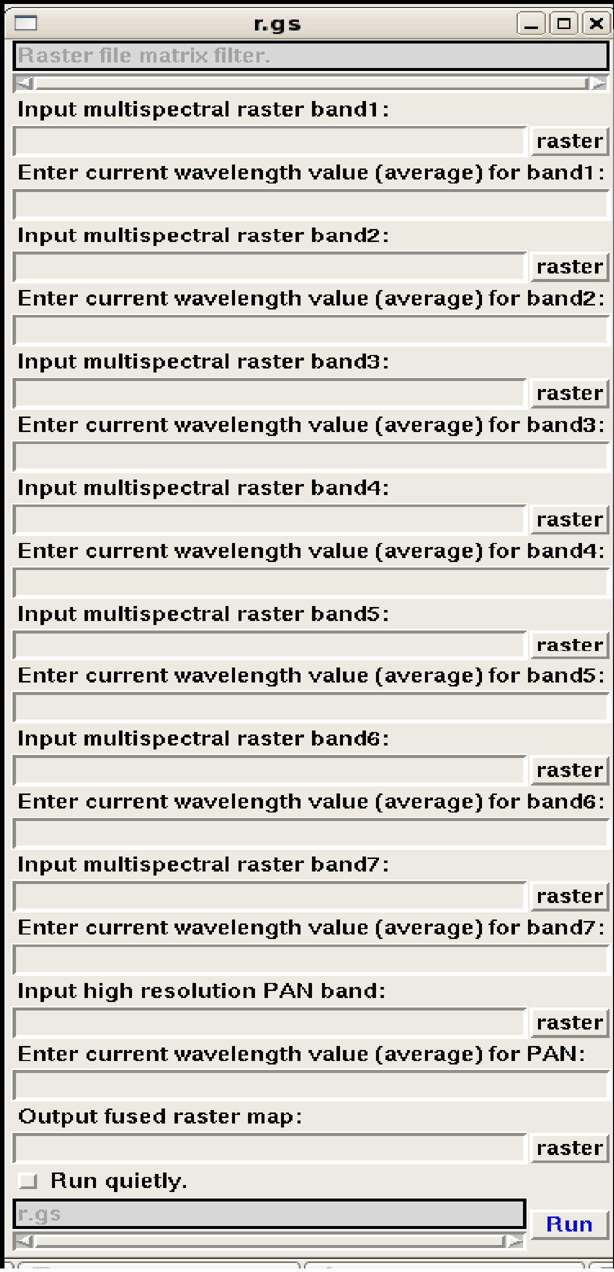




Correspondence Analysis Fusion



Gram Schmidt Fusion



$$B_{wt} = \int_{0.4}^{0.5} OT_B(\lambda) * SR_B(\lambda) * SR_{PAN}(\lambda) \mathrm{d}\lambda$$

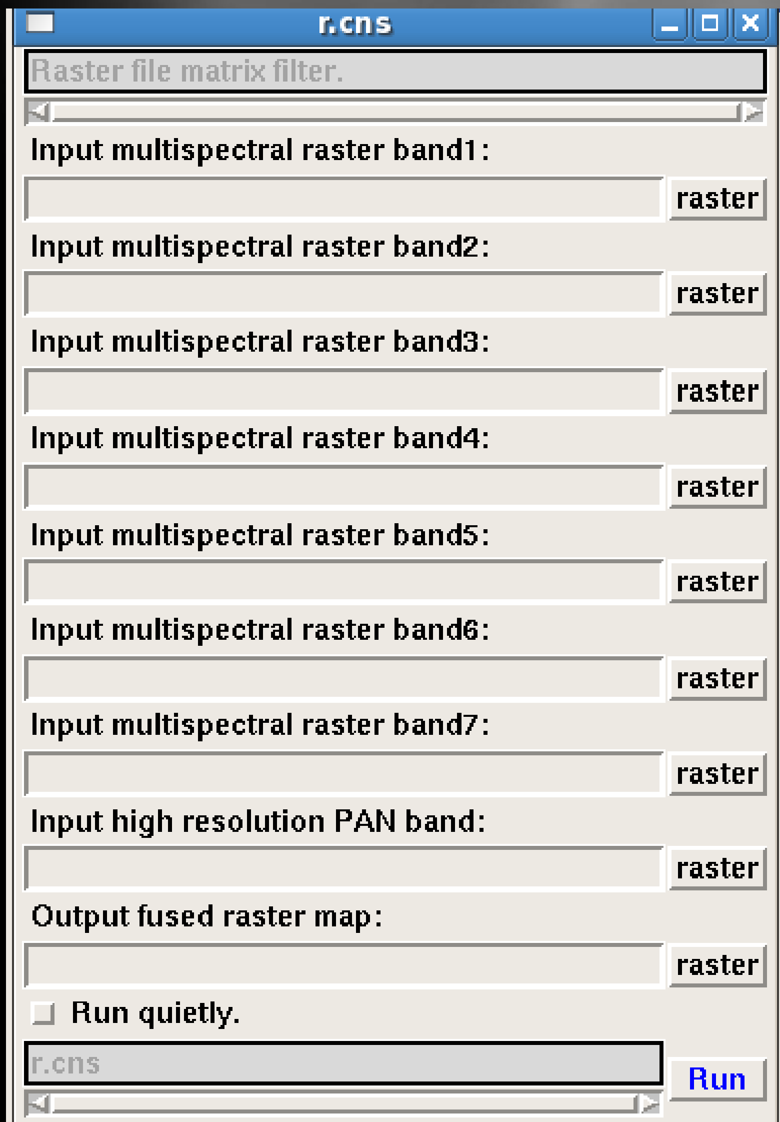
$$G_{wt} = \int_{0.5}^{0.6} OT_G(\lambda) * SR_G(\lambda) * SR_{PAN}(\lambda) \mathrm{d}\lambda$$

$$R_{wt} = \int_{0.6}^{0.7} OT_R(\lambda) * SR_R(\lambda) * SR_{PAN}(\lambda) \mathrm{d}\lambda$$

$$NIR_{wt} = \int_{0.7}^{0.8} OT_{NIR}(\lambda) * SR_{NIR}(\lambda) * SR_{PAN}(\lambda) \mathrm{d}\lambda$$

where OT is the optical transmittance, SR is the spectral response and λ is the wavelength.

CN Spectral Fusion



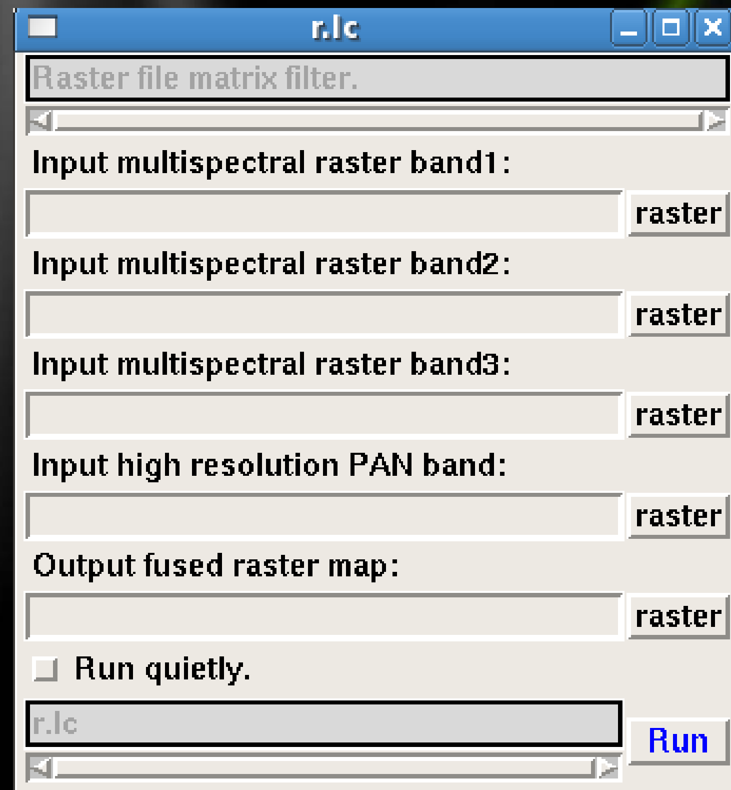
$$MS_i^H = \frac{4(MS_i^L)\cdot PAN}{(\sum_i MS_i^L)+4} - 1$$

where MS_i^H are the fused images, MS_i^L are the LR MS bands, PAN is a HR panchromatic band, and i = band 1 to band 7.

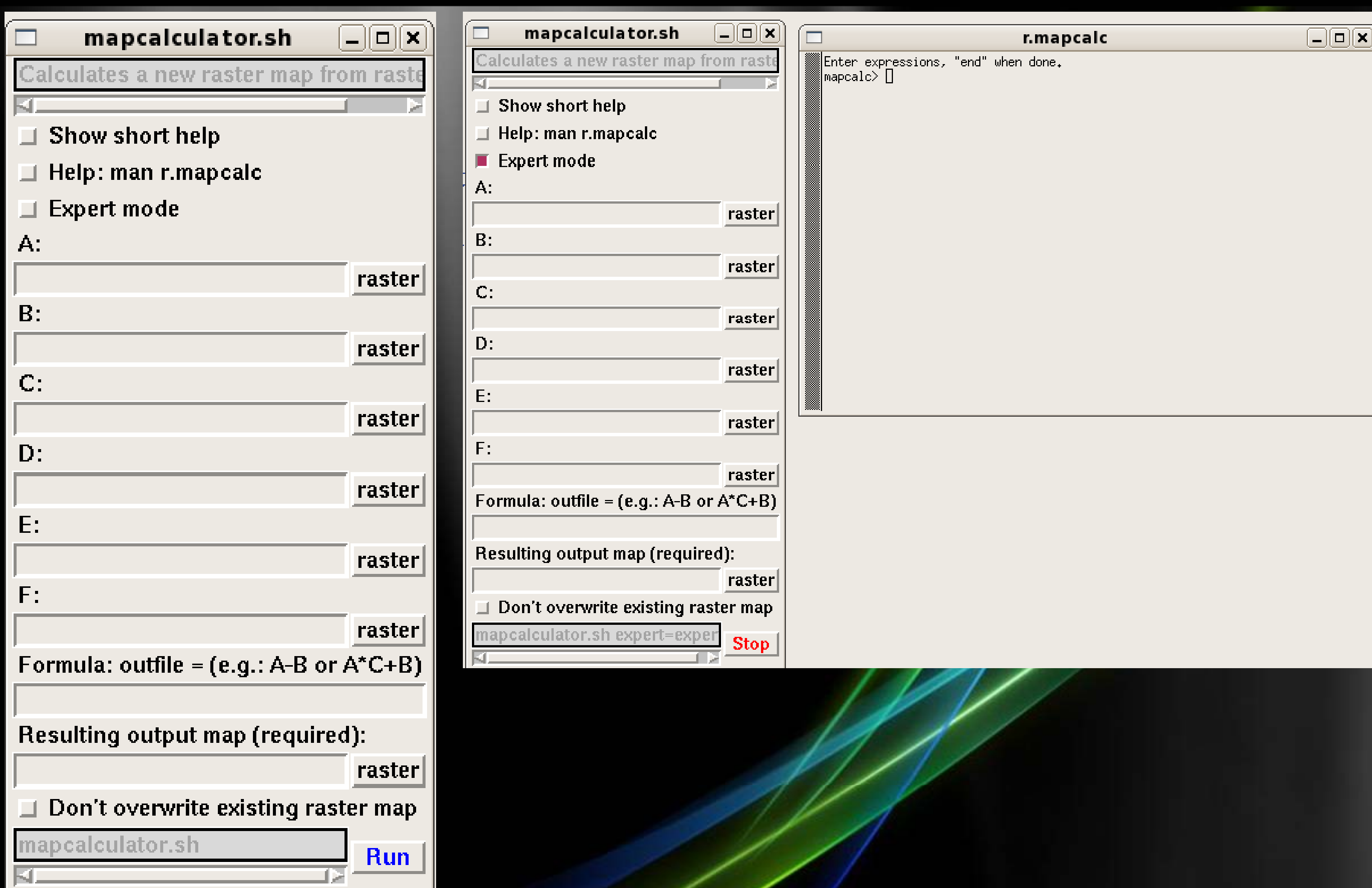
Luminance Chrominance Fusion

$$\begin{pmatrix} Y \\ I \\ Q \end{pmatrix} = \begin{pmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.274 & -0.322 \\ 0.211 & -0.523 & 0.312 \end{pmatrix} \begin{pmatrix} R \\ G \\ B \end{pmatrix}$$

$$\begin{pmatrix} R \\ G \\ B \end{pmatrix} = \begin{pmatrix} 1.000 & 0.996 & 0.621 \\ 1.000 & -0.272 & -0.647 \\ 1.000 & -1.106 & -1.703 \end{pmatrix} \begin{pmatrix} Y \\ I \\ Q \end{pmatrix}$$



GRDSS Map calculator



Results of different fusion techniques

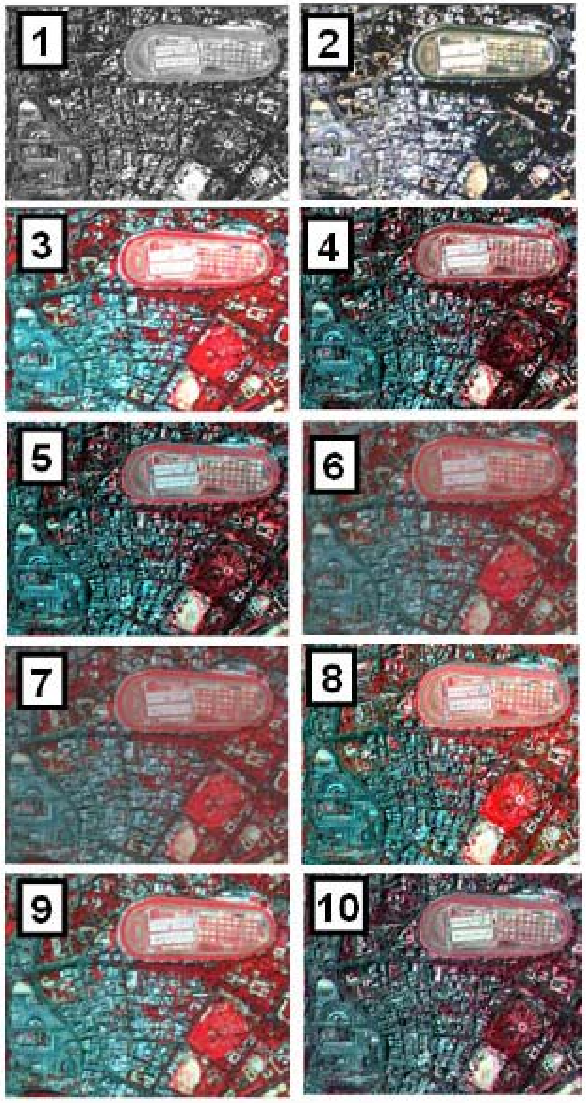


Figure 1. Original PAN image (1), original LR MS image (B-G-R) resampled at 1 m pixel size (2), original LR MS image (G-R-NIR) resampled at 1 m pixel size (3), Fusion through IHS (4), BT (5), HPF (6), HPM (7), PCA (8), FT (9) and CA (10).

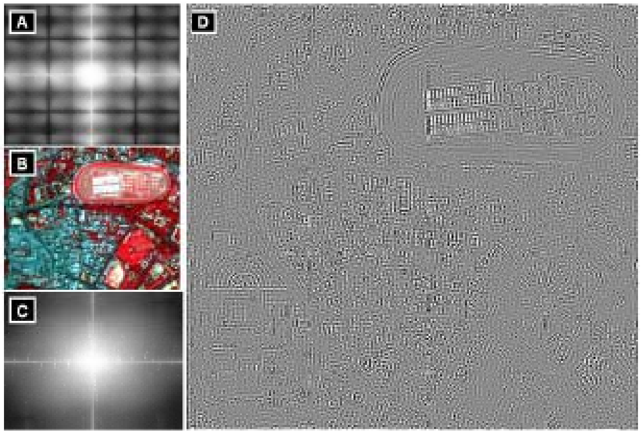


Figure 2. (A) FT on MS (B) Inverse FT on MS, (C) FT on PAN, (D) Inverse FT on PAN.

Results of different fusion techniques

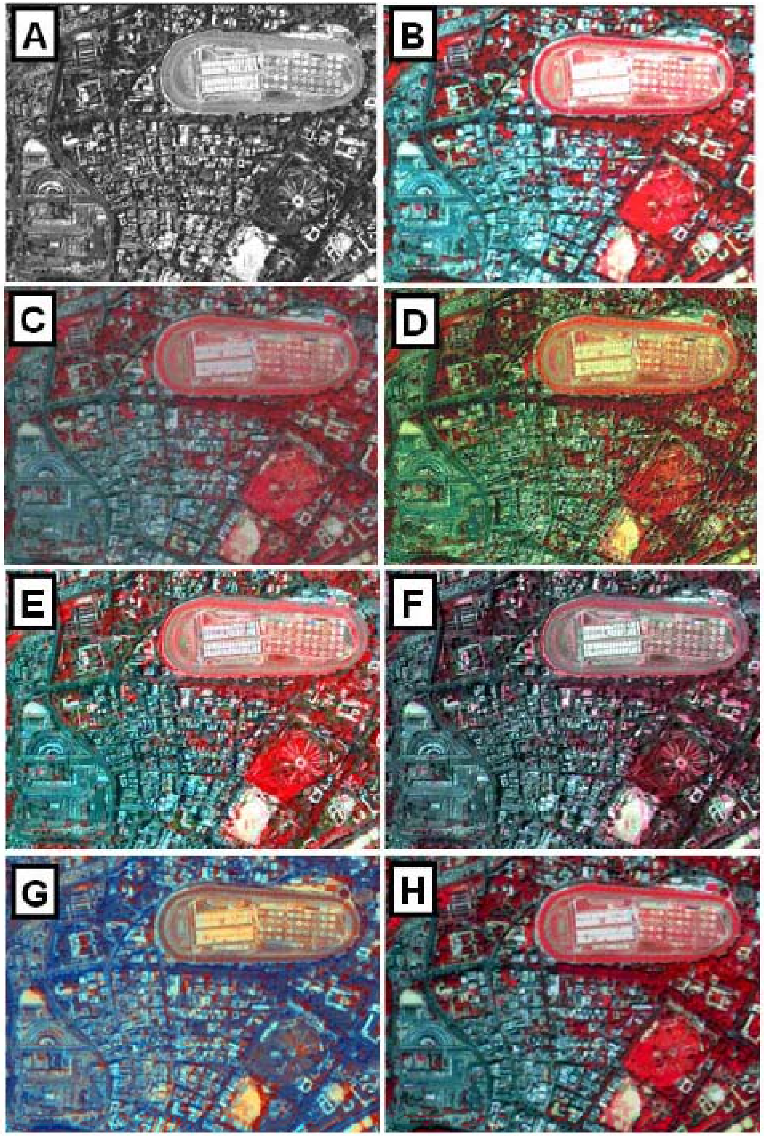


Figure 1. (A) Original PAN image, (B) Original low resolution MS image (G-R-NIR) resampled at 1 m pixel size, fusion results from (C) ATW, (D) MRAIM, (E) GS, (F) CNS, (G) LC and (H) HPF.

Validation

$$Q = \frac{\sigma_{AB}}{\sigma_A \sigma_B} \cdot \frac{2\mu_A \mu_B}{\mu_A^2 + \mu_B^2} \cdot \frac{2\sigma_A \sigma_B}{\sigma_A^2 + \sigma_B^2}$$

CC Closeness Similarity

TABLE 1. UIQI OF FUSED AND ORIGINAL IMAGE

	Blue	Green	Red	NIR
HIS	-	0.17	0.27	0.12
BT	-	0.89	0.97	0.54
HPF	**0.85**	**0.94**	**0.96**	**0.98**
HPM	**0.83**	**0.94**	**0.97**	**0.95**
PCA	0.68	0.63	0.63	0.46
FT	0.43	0.22	0.73	0.81
CA	0.27	-0.01	0.06	-0.00

TABLE 2. CORRELATION BETWEEN IKONOS HR PAN AND CORRESPONDING LR PAN IMAGES FROM DIFFERENT METHODS

IHS	BT	HPF	HPM	PCA	FT	CA
0.32	0.32	**0.95**	**0.95**	0.32	-	0.27
p value for all CC = $2.2e^{-16}$						
Both IHS and BT are limited to 3 bands (G, R and NIR). IHS and BT use the same low resolution PAN image. HPF and HPM use the same low resolution PAN image. There is no generation of low resolution PAN in FT.						

TABLE I.
UIQI MEASUREMENTS OF THE SIMILARITY BETWEEN ORIGINAL AND THE FUSED IMAGES OBTAINED BY VARIOUS METHODS

	Blue	Green	Red	NIR
ATW	0.83	0.92	0.95	0.99
MRAIM	0.81	0.89	0.91	0.93
GS	0.49	0.44	0.46	0.43
CNS	0.12	0.29	0.43	0.43
LC	-	0.12	0.92	0.61
HPF	0.93	0.94	0.93	0.94

TABLE II.
CORRELATION BETWEEN THE IKONOS HR PAN IMAGE AND THE CORRESPONDING LR PAN IMAGE BY DIFFERENT METHODS

ATW	MRAIM	GS	CNS	LC	HPF
0.85	0.80	0.65	-	0.71	0.86
p value for all CC = 2.2e-16					
LC is limited to three bands (G-R-NIR combination). PAN image was used in CNS without any transformation.					

TABLE III.
EVALUATION OF ORIGINAL AND FUSED NIR BAND BY DIFFERENT METHODS

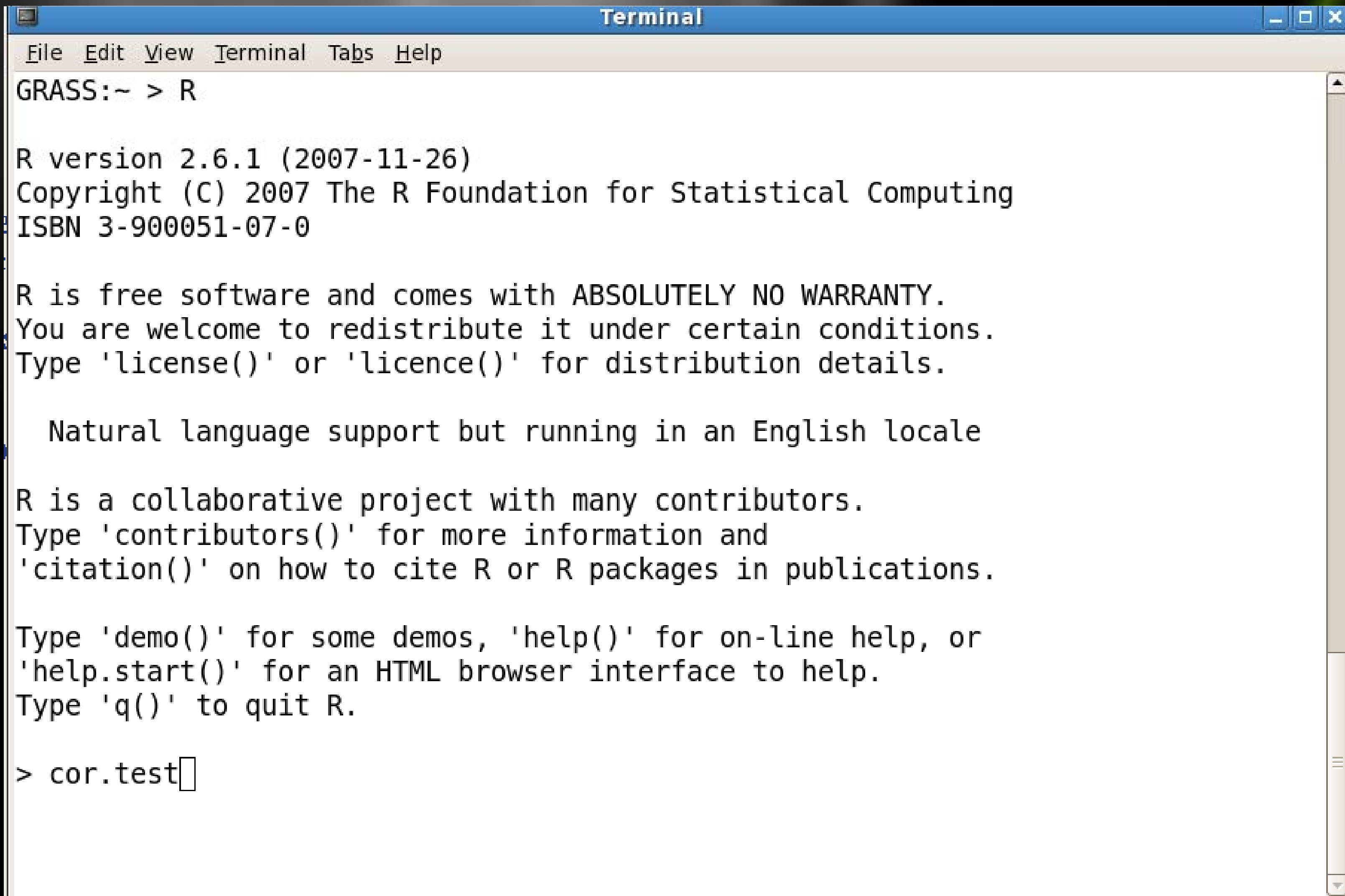
	UIQI	**CC**	**Min**	**Max**	**Sd**
Original NIR	1	1	195	811	87
Fused NIR (ATW)	**0.99**	0.98	125	**867**	**88.5**
Fused NIR (HPF)	0.94	**0.99**	**152**	650	68.1

GRDSS: Interface with R

- The R/GRASS interface substantially improves the geospatial analysis capabilities of GRASS.
- For the integration of R with GRASS, you need to run R from the GRASS shell environment.
- The interface dynamically loads compiled GIS library functions into the R environment.
- GRASS>R> R CMD INSTALL spgrass6_0.3-7.tar.gz
- For more details see:

  OPEN SOURCE GIS
  A GRASS GIS Approach
  Third Edition
  Markus Neteler & **Helena Mitasova**
  Springer

GRDSS: Interface with R



```
Terminal
File  Edit  View  Terminal  Tabs  Help
GRASS:~ > R

R version 2.6.1 (2007-11-26)
Copyright (C) 2007 The R Foundation for Statistical Computing
ISBN 3-900051-07-0

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Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.

> cor.test
```
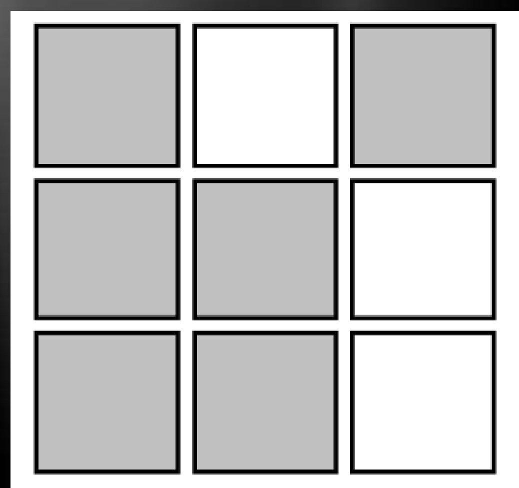

Forest fragmentation

- Forest fragmentation is the process whereby a large, continuous area of forest is both reduced in area and divided into two or more fragments (K. J. Ritters et al., 2000).

- For calculating forest fragmentation and its occurrence as adjacent pixels, fixed-area windows surrounding each forest pixel is used.



Pf equals 6/9=0.67

Total number of adjacent pixel pairs is 12, and of these, 11 pairs include at least one forested pixel. Five of those 11 pairs are forest-forest pairs. Pff equals 5/11 = 0.45

K. J. Riitters, R. O' Neill. Wickham, B. Jones, and E. Smith, "*Global-scale patterns of forest fragmentation*," Conservation Ecology, vol. 4, no. 2-3, 2000.

Forest fragmentation

The six fragmentation model that identifies six categories are:

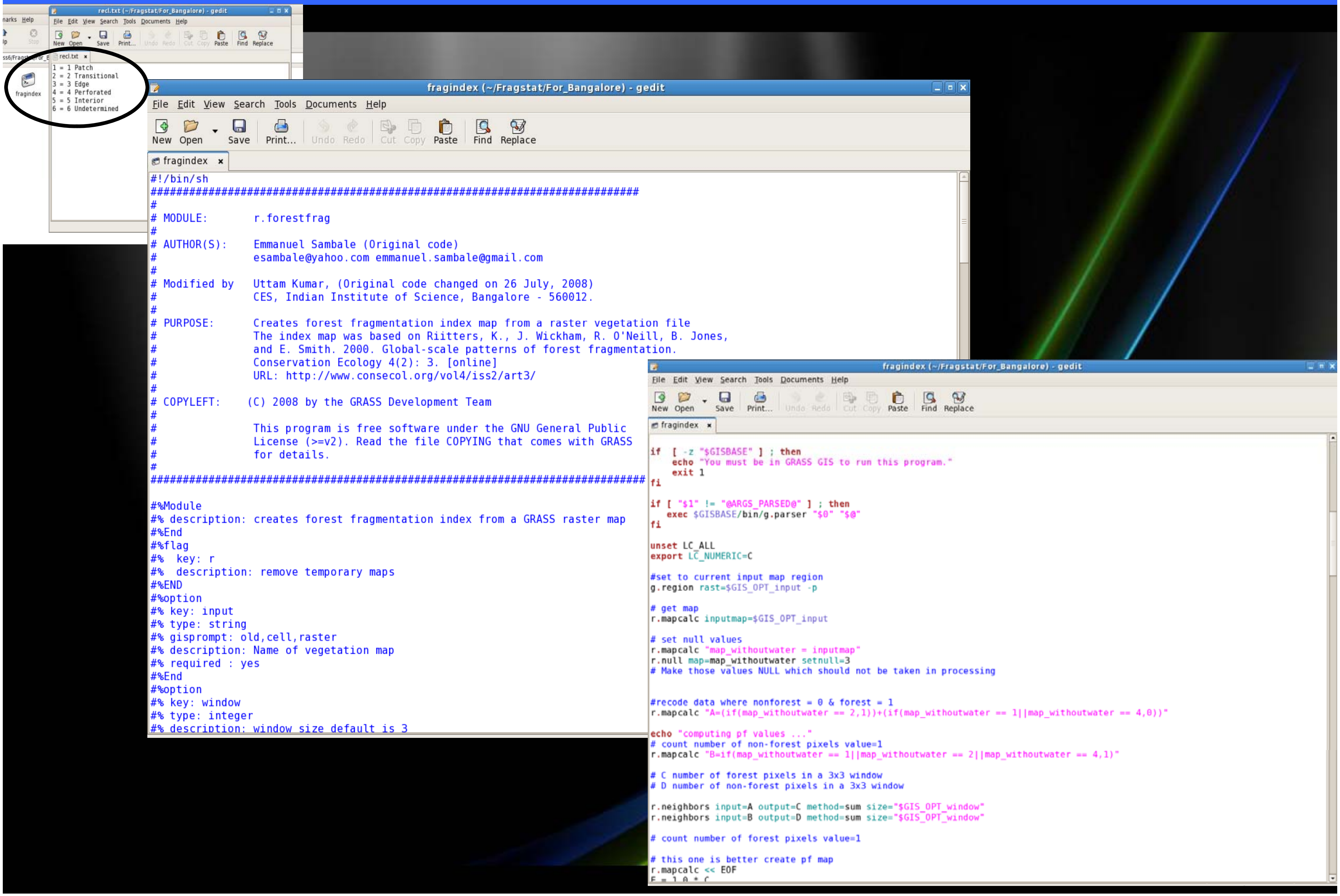
(1) Interior	(Pf = 1.0)
(2) Patch	(Pf < 0.4)
(3) Transtitional	(0.4 < Pf < 0.6)
(4) Edge	(Pf > 0.6 and Pf – Pff > 0)
(5) Perforated	(Pf > 0.6 and Pf – Pff < 0) and
(6) Undetermined	(Pf > 0.6 and Pf = Pff)

$$TFP = \frac{total\ forest\ area}{total\ non - water\ area}$$

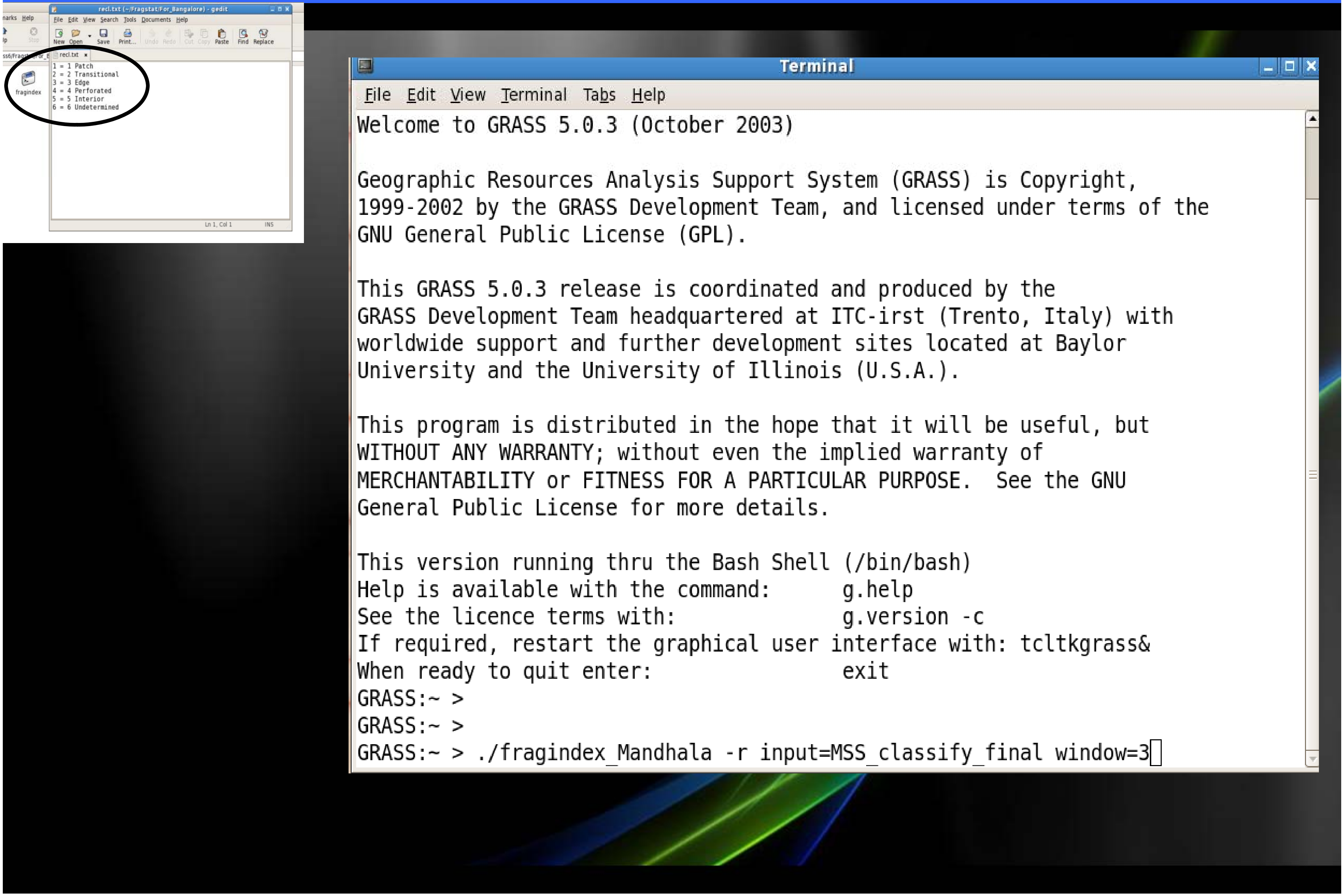
$$FC = \frac{weighted\ forest\ area}{total\ forest\ area} * \frac{area\ of\ largest\ interior\ forest\ patch}{total\ forest\ area}$$

$$\text{WFA} = (1.0 * \text{interior}) + (0.8 * (\text{perforated} + \text{edge} + \text{undertermined}) + (0.5 + \text{transitiojnal}) + (0.2 * \text{patch})$$

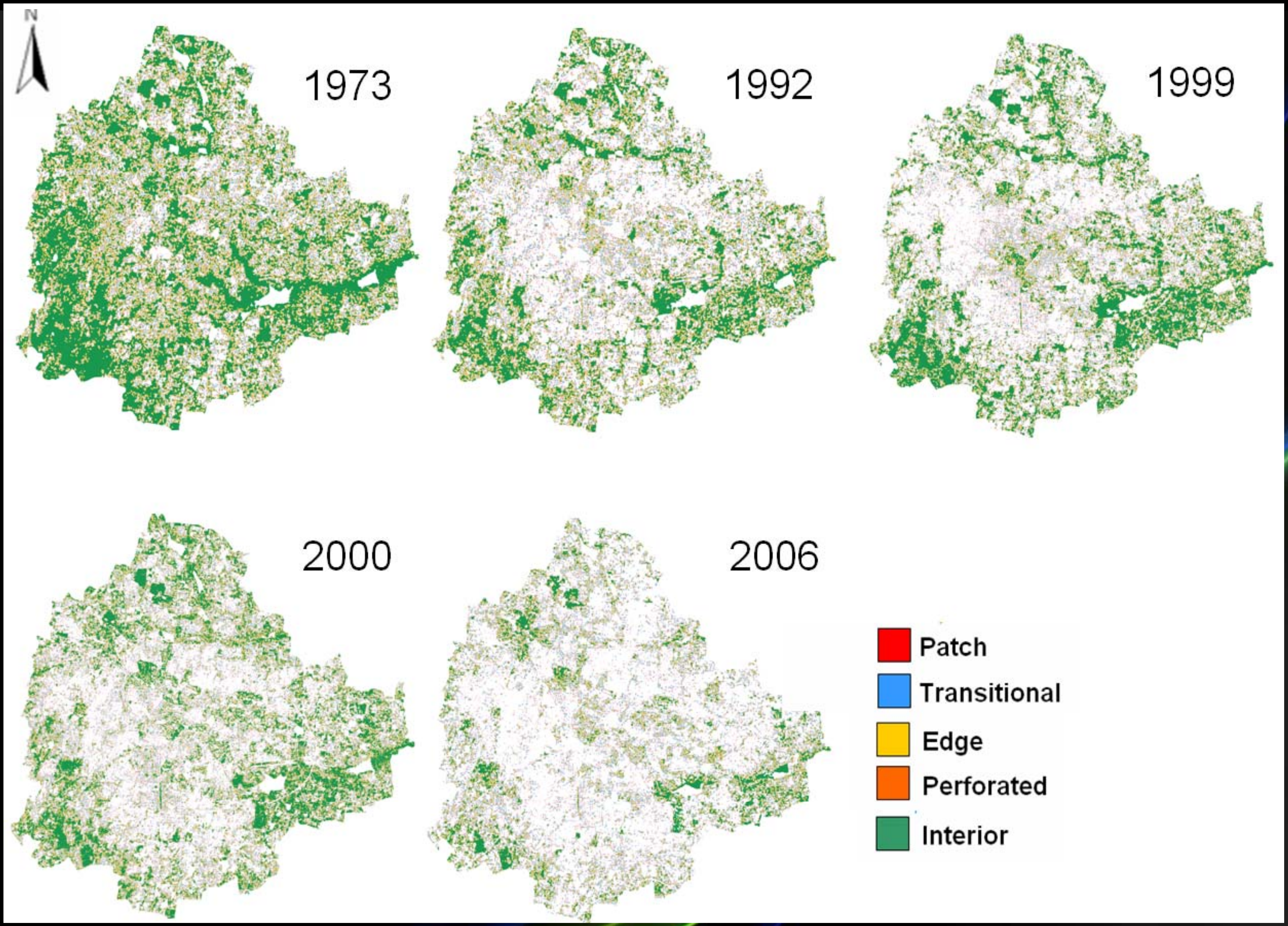
Forest fragmentation



Forest fragmentation



Forest fragmentation 1973 - 2006



Forest fragmentation

Forest Fragmentation Categories	1973		1992		1999		2000		2006	
	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%
Patch	1120	**2.45**	1950	6.34	1788.6	5.91	1944	6.47	1810	**9.57**
Transitional	3789	8.28	4259	13.84	3816	12.62	3999	13.31	3956	20.92
Edge	14717	32.16	10709	34.81	9516	31.46	10593	35.25	6050	31.99
Perforated	1453	3.18	1447	4.70	1410	4.66	1219	4.06	1859	9.83
Interior	24675	**53.93**	12401	40.31	13715	45.35	12291	40.91	5236	**27.69**
Total	45756	100	30766	100	30244	100	30047	100	18909	100

Total forest proportion and forest continuity

State of forest fragmentation index	1973	1992	1999	2000	2006
TFP	0.71	0.48	0.47	0.46	0.29
FC	0.45	0.30	0.34	0.30	0.19

Urban fragmentation

- The urban growth model (D. L. Civco et al., 2002) uses multi-dates urban (developed) and non-urban (non-developed) classes.
- Interior - all pixels in a *3* x *3* window are non-developed.
- Perforated - when > 60 % and < 100 % of pixels in a *3* x *3* window are non-developed.
- Patch - < 60 % of pixels in a *3* x *3* window are non-developed.

D. L. Civco, J. D. Hurd, E. H. Wilson, C. L. Arnold, and M. P. Prisioe, "*Quantifying and Describing Urbanizing landscape in the Northeast United States*," Photogrammetry Engineering and Remote Sensing, vol. 68, no. 10, pp. 1083 - 1090, 2002.

Urban fragmentation

Significant Change Classes	Type of Growth
Patch to Developed	Infill Growth
Perforated to Developed	Expansion Growth
Interior to Developed	Outlying Growth: *Isolated, Linear Branching, Clustered Branching Growth*

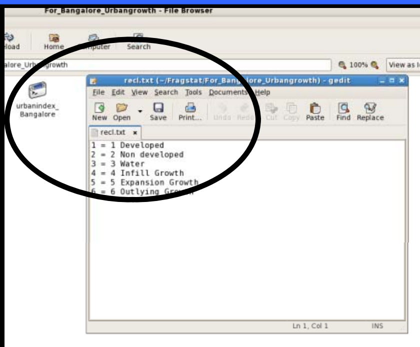
Infill – development surrounded by existing developed land.

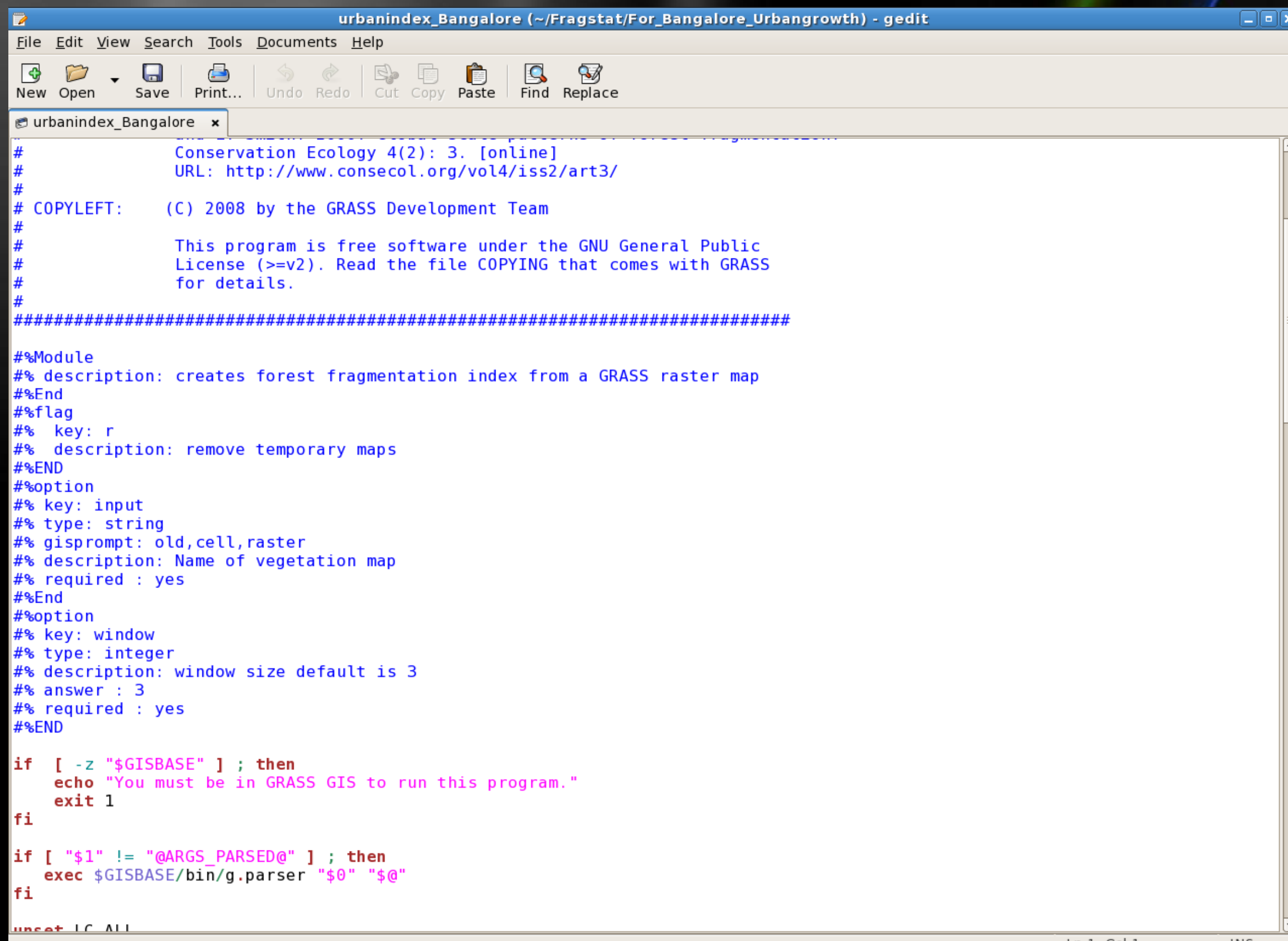
Expansion - spreading out of urban LC from existing developed land.

Outlying growth - interior pixel that changes to developed.

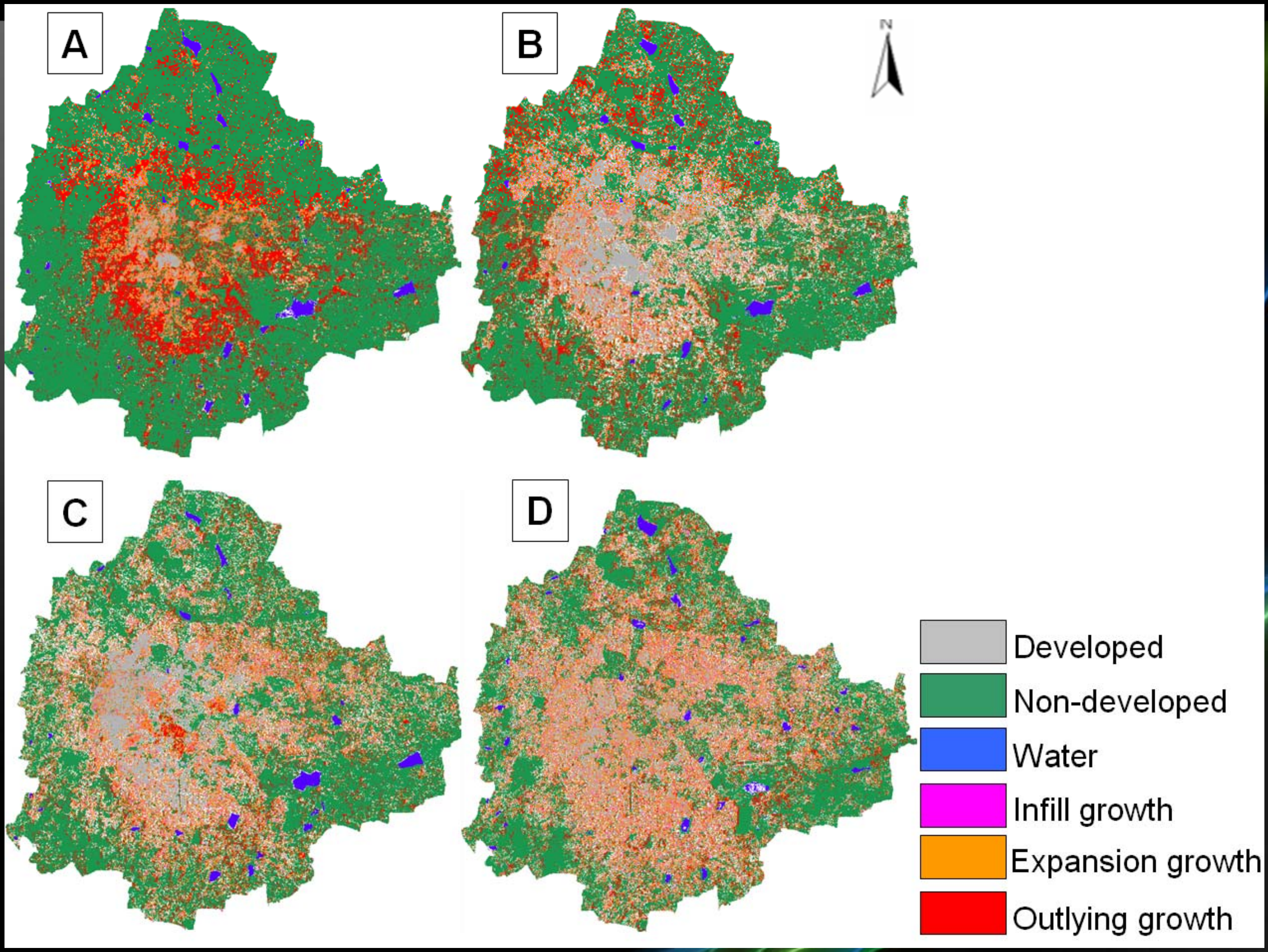
- An isolated growth - new, small area of construction surrounded by non-urban land and some distance from other developed areas.
- A linear branching growth - is a road, corridor, or linear development.
- A clustered branching - new, large and dense development in a previously undeveloped area.

Urban fragmentation





Urban fragmentation



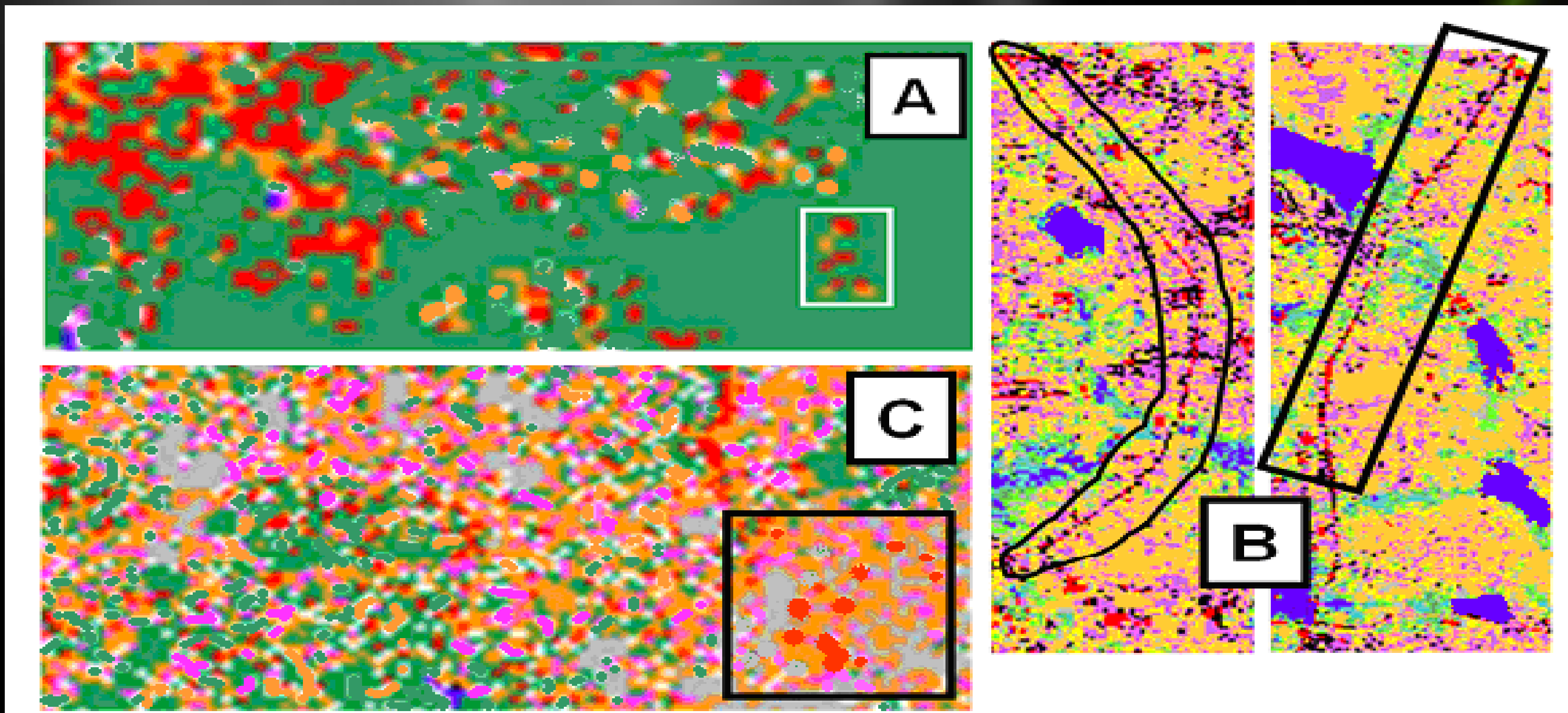
Urban growth map (A) 1973 to 1992, (B) 1992 to 1999, (C) 1999 to 2000, (D) 2000 to 2006.

Urban fragmentation

Changes in urban growth types from 1973 to 2006

Urban Growth Type	1973 - 1992		1992 - 1999		1999 - 2000		2000 - 2006	
	Ha	%	Ha	%	Ha	%	Ha	%
Developed	6889	1.01	3818	5.60	2876	4.22	32380	4.74
Non-developed	48529	71.3	44034	64.6	42610	62.5	37922	55.54
Water	905	1.33	692	1.01	1434	2.10	952	1.39
Infill	720	1.06	2146	3.15	3088	4.53	4232	6.20
Expansion	5720	8.40	10078	14.8	13110	19.2	16412	24.04
Outlying	11520	16.9	7453	10.9	5054	7.41	5526	8.09
Total	68082	100	68220	100	68172	100	68282	100

Urban fragmentation



Types of urban outlying growth highlighted in box –

(A) isolated growth,
(B) linear branching (road/corridor),
(C) clustered growth.

Urban fragmentation

- Forest fragmentation model shows that Interior forest which was present in the city up to 54 % (in 1973) has come down to 28 % in 2006.
- Urban growth characterised by developed, infill, expansion and outlying types evidently illustrate the phenomenon of urbanising Greater Bangalore.

Landscape analysis with r.li

Landscape analysis is the study of the variation in landscape over multiple spatial and temporal scales (IALE, 1998).

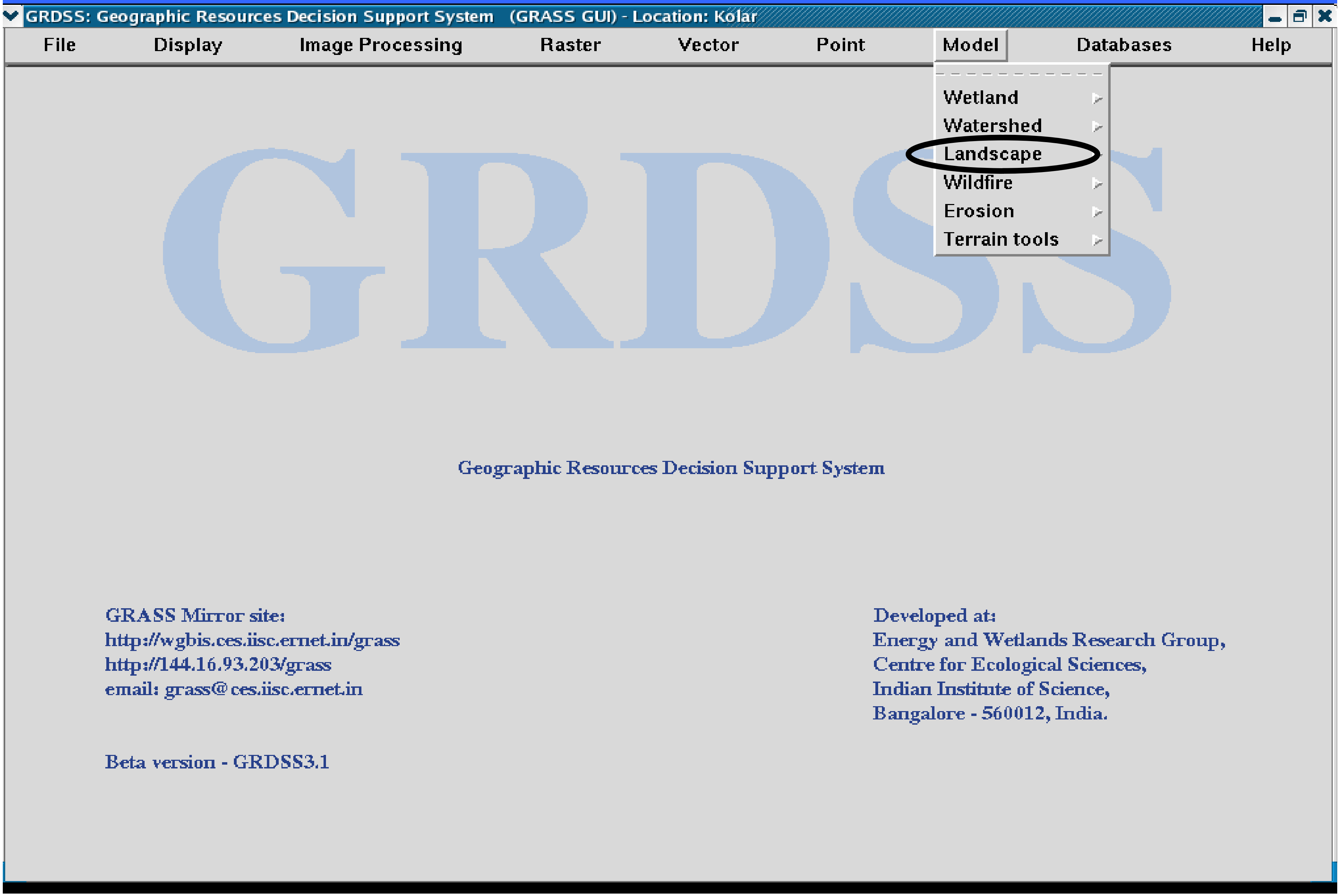
The r.li program in GRASS is written for landscape analysis (Baker, 1992; Baker, 2001).

IALE, 1998. IALE mission statement. IALE Bulletin 16(1), 1.

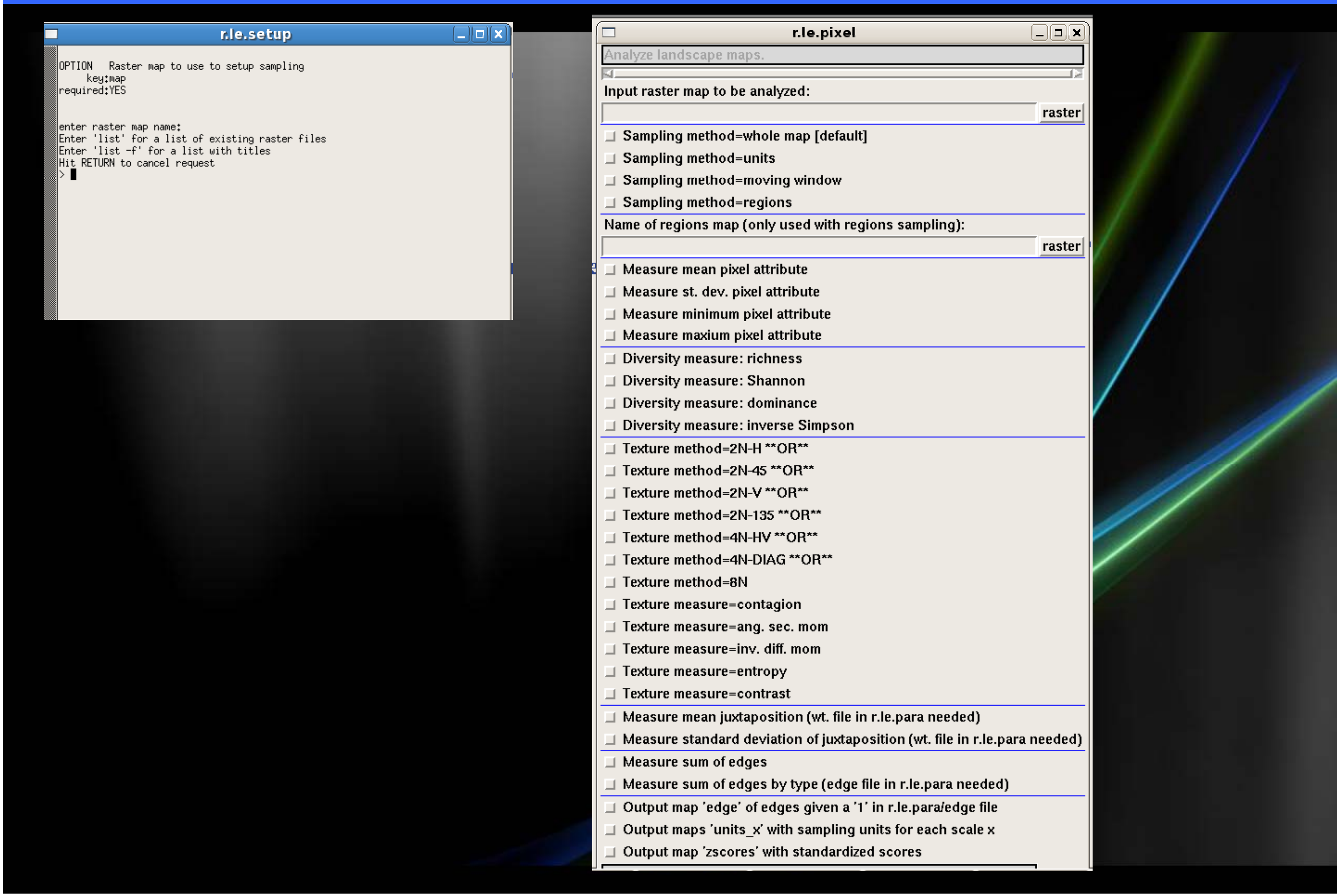
Baker, W.L., Cai, Y., 1992. The r.le programs for multiscale analysis of landscape structure using the GRASS geographical information system. Landscape Ecology 7, 291–302.

Baker, W.L., 2001. The r.le programs: a set of GRASS programs for the quantitative analysis of landscape structure. Department of Geography. University of Wyoming.

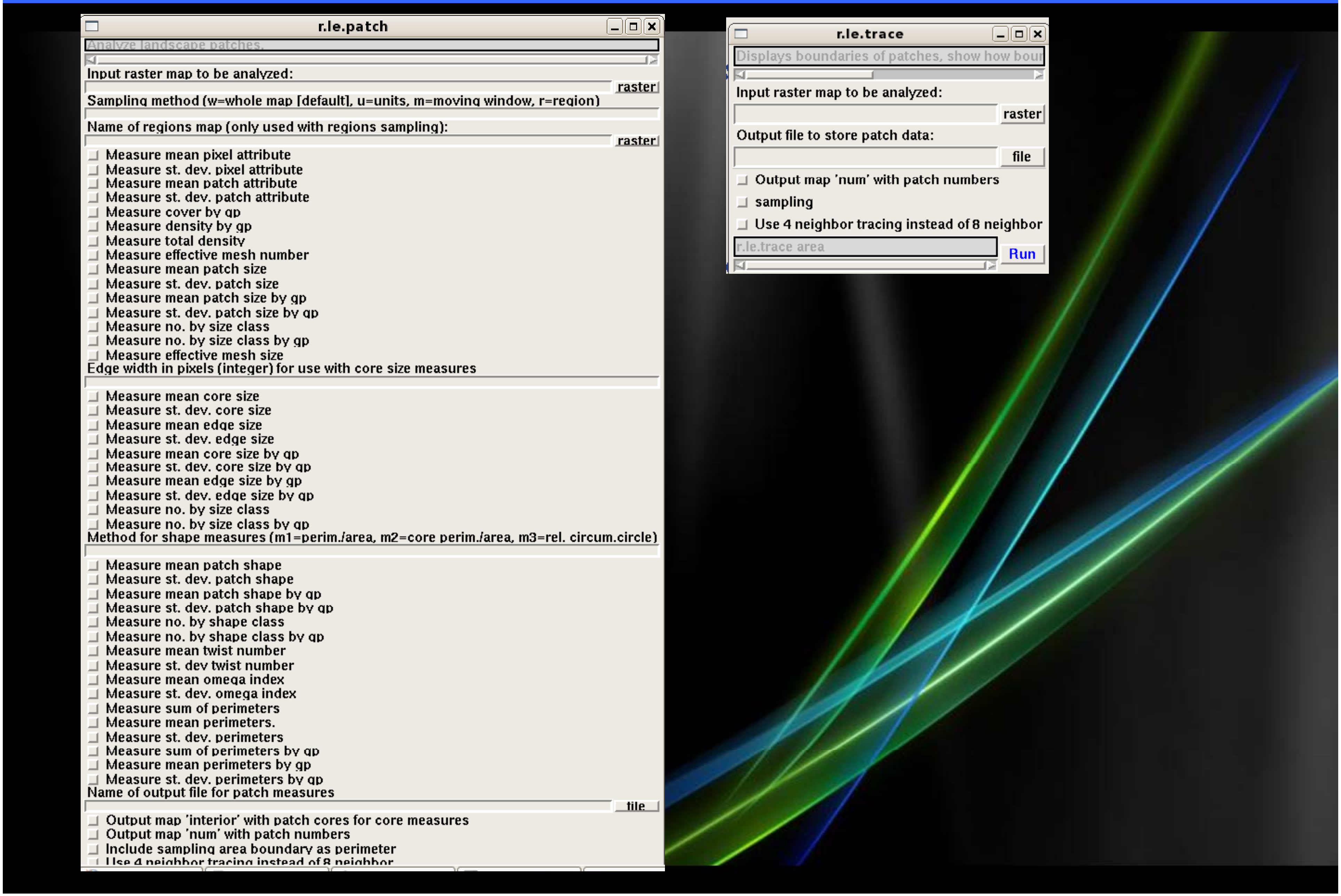
Landscape analysis with r.li



Landscape analysis with r.li



Landscape analysis with r.li



Conclusions

- Addition of band extraction, image fusion, forest/urban fragmentation modules and landscape analysis tool
- We advocate more wide publicity and use of FOSS GIS.
- We recommend that FOSS community considers directing their efforts towards a common software development effort within FOS GIS, and establish specific user and developer forums.
- We suggest to have some ideal location or repository for such developmental activities with links to special interest groups who could concentrate on specific research related plug-ins.
- If such unified software development and research efforts could be initiated then we expect great potential to accelerate FOSS4G research in India.

Future directions: Road map to FOSS4G

- Integration of GRDSS with QGIS
- Modules for Hyperspectral Image Processing
- Easy interface of GRASS with R
- Modules for SAR image processing
- Addition of advanced pattern recognition techniques
- Inclusion of OBIA techniques