Using the Open GIS AGNPS-GRASS Module

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Abstract

Open Source software such as GRASS is of great interest to many users and developers. One principle advantage is that users can develop and adapt to suit their purposes.

However it can be difficult for the novice user to understand the operation and use of some modules. This difficulty can be both with the concepts of calculations and processes as well as with interpretation of the outputs.

This paper presents a document aimed at a first time user of the AGNPS-GRASS module. This module is based on the algorithm of version 5.00 of the Agricultural Non-Point Source Pollution model (AGNPS) and was first developed by Srinivasan and Engel (1992). It is an event based, distributed parameter soil erosion model that calculates runoff, peak flow rate and sediment yield over agricultural areas. Parameterising the model requires different 22 input data layers. Whilst the AGNPS-GRASS module makes the actual input procedure simple, the preparation of these input data layers from other base data can be a considerable task.

This paper also describes the process of running the AGNPS-GRASS 5.00 module using the standard GRASS “Spearfish” training dataset. the paper. The methods used to create each of the 22 input layers will be described. The output layers and tables will be discussed together with a method for included a scheme how to calibrating and validating the module. Finally the structure of code will be discussed for the benefit of developers and some modifications to the code will be suggested.

Keywords: AGNPS ; GIS; GRASS; Soil loss

Introduction

The AGNPS model was originally developed by United States Department of Agricultural Research Service (USDA-ARS) (Young *et al.*, 1987;1995 cited in Najim, 2000). AGNPS is the single event base and parameter simulation model. The model is used to predict surface runoff volume, peak flow rate, soil loss, sediment, nutrient and pesticide yield (Najim, 2000; Grunwald and Norton, 1999; 2000).

AGNPS model has become popular for the evaluation of sediment and nutrient yield in a variety areas. Haregeweyn and Yohannes (2003) applied AGNPS model in Augucho catchment, western Hararghe, Ethiopia, Leon *et. al.* (2004) in southern Ontario, Pekarova *et. al.* (1999) in Slovak Microbasins, Perrone and Madramootoo (1999) in Quebec, Rode and Frede (1999) in the state of Hesse (Germany) and Najim (2000) in Chanthaburi, Thailand.

The model has been coded as standlone software for both UNIX and DOS PC's operateing systems. The latest versions of AGNPS program is 5.00. Currently, AGNPS model is linked or integrated to GIS software such as Arcview and Arc/Info (Ma *et. al.*, 2001), ERDAS Imagine's Spatial Modeler (Finn *et. al.*, 2002), RAISON (Leon *et. al.*, 2000), SPANS (Grunwald and Norton, 2000) and GRASS (Srinivasan and Engel, 1992).

Geographic Resources Analysis Support System (GRASS) was developed in 1982-1995 by U.S Army Corps of Engineers Construction Engineering Research Laboratory (CERL). GRASS is an open source software under GNU General Public License (GPL). At present, GRASS development is lead by the GRASS Development Team (Mitasova, H. and Neteler, M., 2002).

AGNPS-GRASS module, created by Srinivasan and Engel (1992), is an add on module in

GRASS which provides an integrated system of AGNPS model and GIS software. GRASS is used to prepare input data in AGNPS's input format, perform calculations base on AGNPS model version 5.00 and view the results of calculation. Since 1992, AGNPS-GRASS has been modified and corrected but some difficulties remains with its operation.

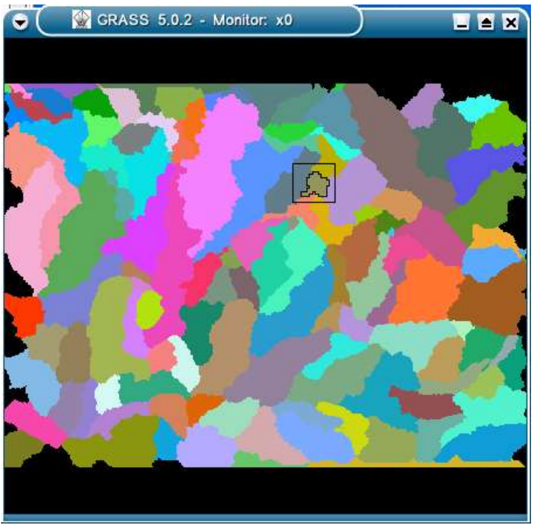
Therefore, this paper will present some of corrections that can be made to enable the AGNPS-GRASS module to run and correctly display the results.

Spearfish Sample Database

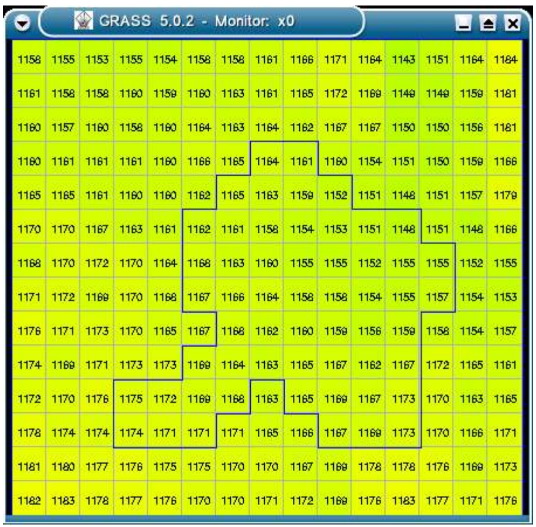
The Spearfish database was originally provided to USACERL by the EROS Data Center (EDC) in Sioux Falls, SD. The GRASS Development Team distributes this data set to GRASS's user via GRASS's website. The location of Spearfish is in western South Dakota in the United States of America. The data set covers coordinate N 4928000, S 4914020, W 590010 and E 609000 and it has 30 m. grid cell size.

A small watershed, basin.wshd, in the Spearfish region is defined by r.watershed module as showed in Figure 1. This watershed is located between coordinates N 4925100, S 4923700, W 600500 and E 602000 and is 0.56 km^2 in area. It was defined at a horizontal resolution of 100 m. Soils in this watershed Basin is 60.7% silty loam, 1.8% silt loam and loam and 21.4% lobbly loam. Soil types in *basin* watershed are in texture layer of Spearfish. Percentage of sand and clay are assumed from US Department of Agriculture textural classification chart by using soil types. Aspect layer calculates from neighborhood technique and reclassed to 1-8 as category values of AGNPS direction shows in Figure 2. The elevation varies betweem 1148-1175 m. The other layers for **r.agnps50.input** are shown in Figure 1. Parameters for USLE of interesting area can be found from grovernment's agency such as Land Development Department (2000). Pesticide layer has up to 3 scenarios can be put as category values 1, 2, or 3 (GRASS Development Team, 2002). Channel slope and slope length factor are calculated by AGNPS-GRASS. For details of each scenarios will be entered by **r.agnps50.input**.

Precipitation parameters are default values shows in Figure 3. For channel, fertilizer and pesticide informations are assumed.

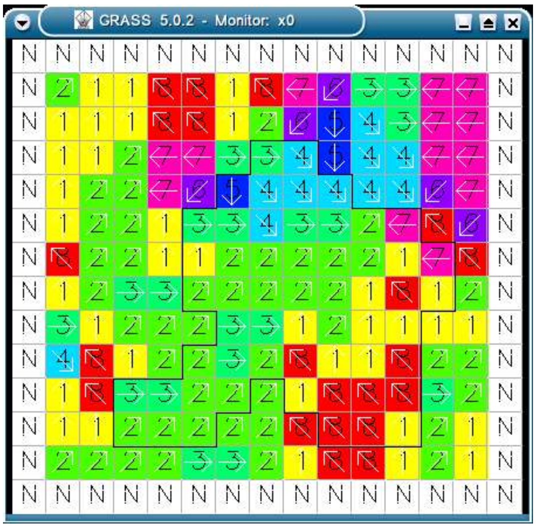


basin.wshd

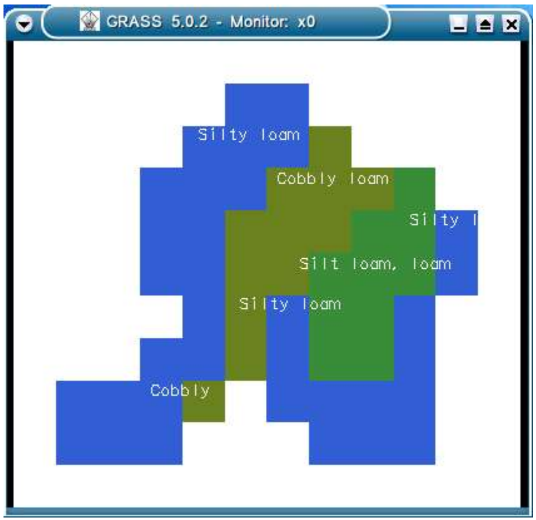


basin.elev

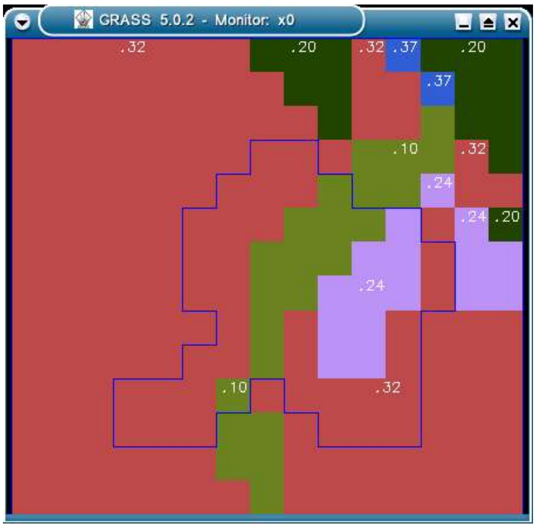
Figure 1 The selected watershed and input layers for r.agnps50.input.



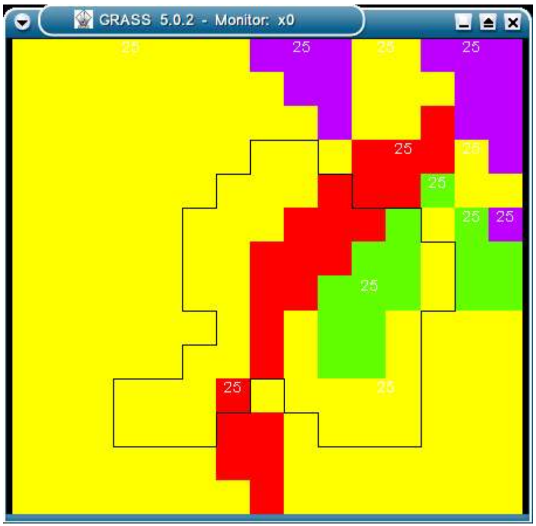
basin.asp.100



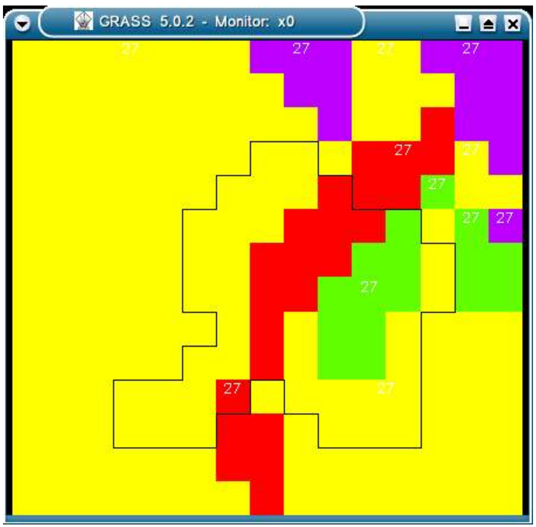
basin.soils



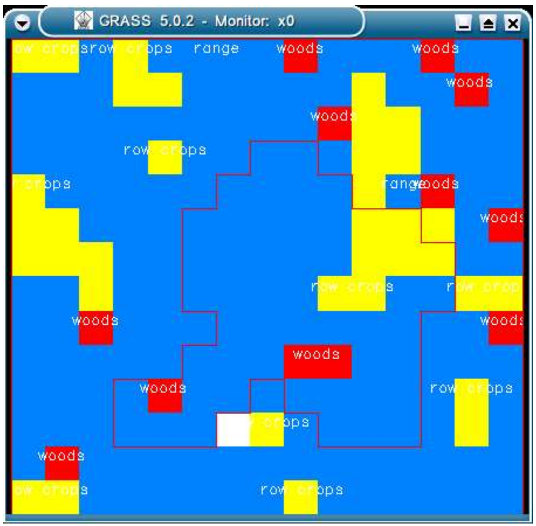
basin.K



basin.sand

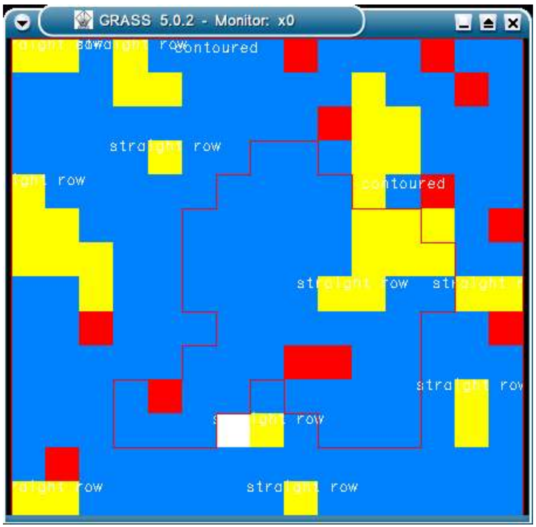


basin.clay

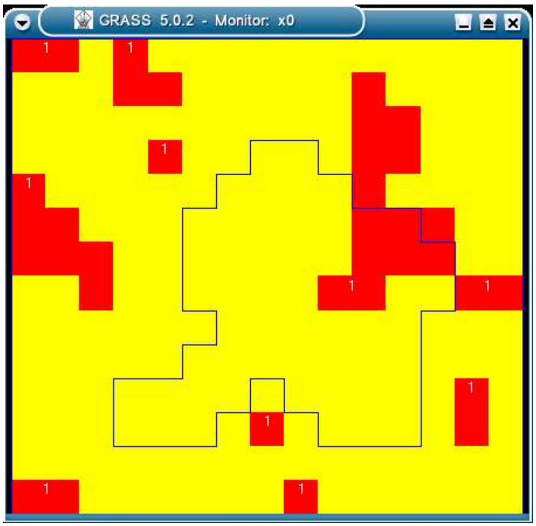


basin.luse

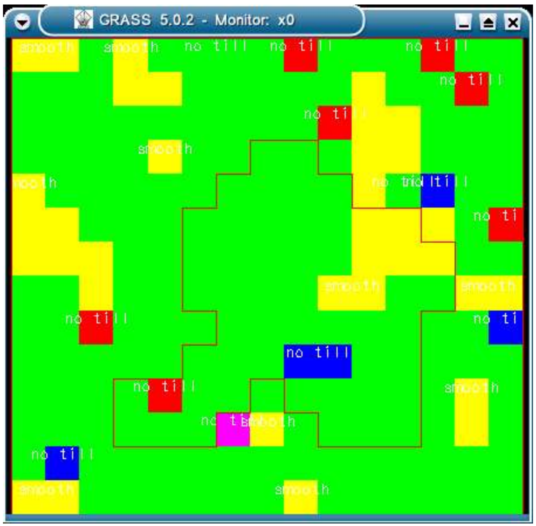
Figure 1 The selected watershed and input layers for r.agnps50.input (cont.).



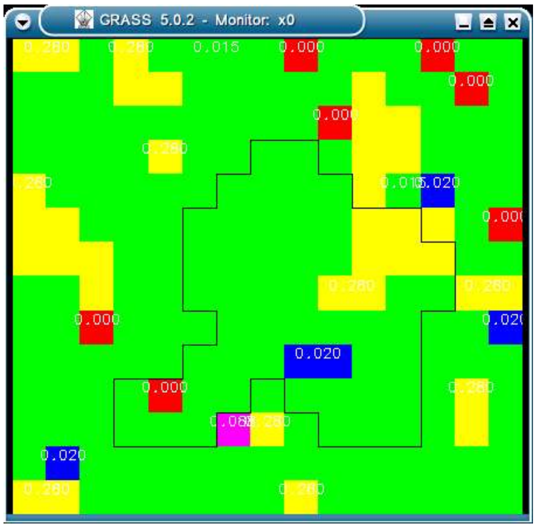
basin.mgpr



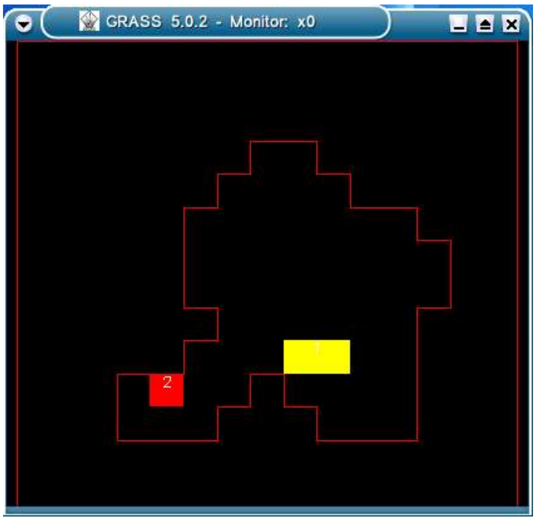
basin.nut



basin.mach



basin.C



basin.pest

Figure 1 The selected watershed and input layers for r.agnps50.input (cont.).

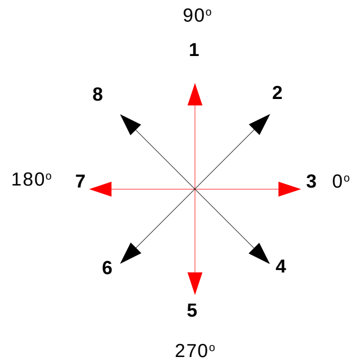


Figure 2 The Aspect categories of AGNPS (1-8) and angle values from neighborhood technique.

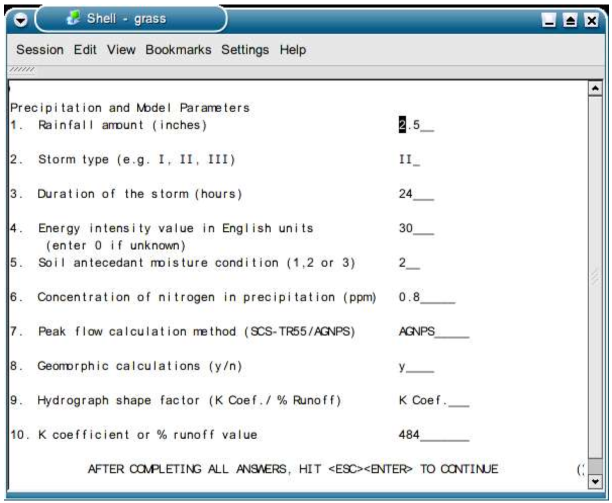


Figure 3 Precipitation parameters.

The AGNPS-GRASS module

The test setup for AGNPS-GRASS was run under the Linux TLE 5.5 operaring system and GRASS is version 5.0.2. The following sub-modules are used: **r.agnps50.input**, **r.agnps50.run** and **r.agnps50.view**. **r.agnps50.input** is used to create an input data file has *.dat extension. This input data file is passed to **r.agnps50.run** sub-module, which performs the main processing. This creates output or result files, with the following extensions *.hyd, *.dep, *.gis, *.imp, *.src and *.nps. These result files can be viewed in GRASS environment using **r.agnps50.view** sub-module. In the file names above * represents the name of the input basin, keeping consistency throughout the data set.

Five problems were encountered with running AGNPS-GRASS. 1) the problems accessing the input interface, 2) the r.cn module cannot find temp_cn file, 3) the user cannot specify and select cells in the layer when required, 4) the cell size with more than 2 digits cannot be used in **r.agnps50.view**, 5) the result layers cannot view properly. The following sections deal with each of these problems in turn.

<u>Starting the user interface</u>

The user can get into AGNPS-GRASS input's interface by placing the name of watershed fafter the command line input r.agnps50.input module such as "r.agnps50.input *basin*" where basin is the name of watershed.

Problems with r.cn module

The r.cn module is used to calculate runoff curve number layer for runoff calculation. The error message “cannot find temp_cn file” is generated because AGNPS-GRASS does not correctly create the required *temp_hy_cond* layer. The temp_hy_cond is a GIS layer that contains information about the hydrologic condition “good”. The user can correct this error by using **r.reclass** module to create *temp_hy_cond* layer. The **r.cn** module is then re-run and finally the **r.agnps50.input** is run again. Figure 4 shows the dialouge associated with the **r.cn** error.

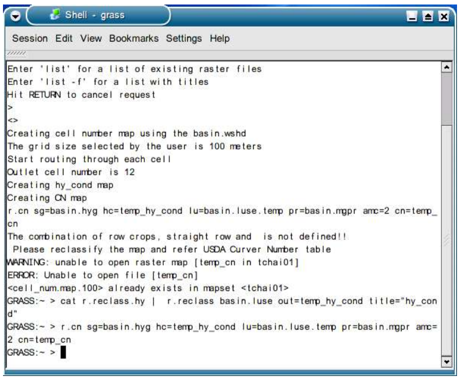


Figure 4 r.cn module error.

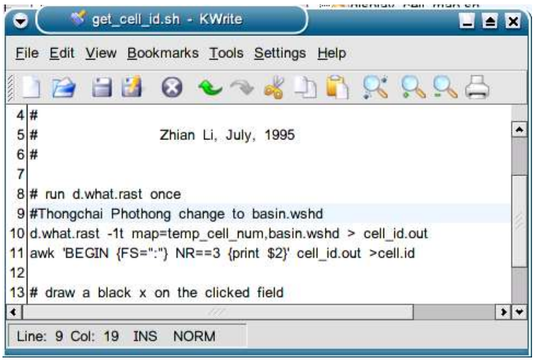


Figure 5 The watershed's name correction.

Specifying cells in the input layer

The user may wish to specify a cell in the numbering layer, for example to locate a point source such as feedlot or channel. Problems in the code of AGNPS-GRASS module only allow the user to locate point sources when using the ANSI database. This can be overcome by changing The watershed name *ansi.wshd* to *basin.wshd* in “grass5.0.2/src/raster/r.agnps50/scripts/get_cell_id.sh” file. Figure 5 shows a name changing example.

Cell sizes greater then two digits

If the user want to use a cell size with more than two digits then GRASS will display “Segmaentation Faluts” when the user tries to view a result layer. This can be corrected by altering the code in file “//grass5.0.2/src/raster/r.agnps50/agviewa/show_maps.c”. The array must be changed as shown in Figure 6.

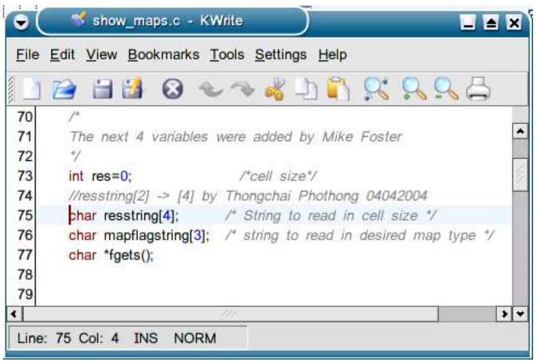


Figure 6 The array's size correction.

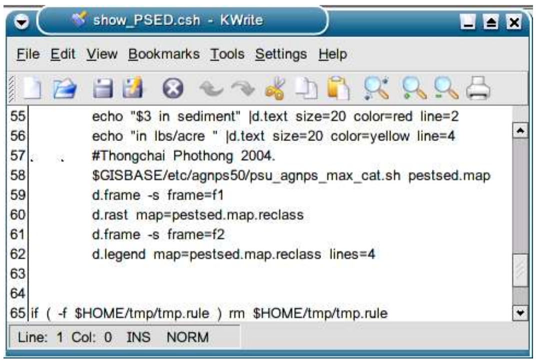


Figure 7 The view script correction.

Displaying result layers

When problems are encountered with viewing the result and pesticide layers further corrections to the code are needed. The text “$GISBASE/etc/agnps50/” needs to be added before the words “psu_agnps_max_cat.sh pestsed.map” in three files in the directory “/grass5.0.2/src/raster/r.agnps50/scripts/show_PPERC.csh, show_PRUNOFF.csh and show_PSED.csh. Figure 7 shows an example.

Parameterising the method

AGNPS model requires 22 parameters. AGNPS-GRASS provides these as 13 layers (included soil types layer) and some input parameters (Figure 1). Table 1 shows the AGNPS input parameters and their method of preparation in AGNPS-GRASS. Figure 8 shows the work flow for **r.agnps50.input** which creates the basin.dat file.

	AGNPS model	AGNPS-GRASS module
1	Cell number	Using a watershed layer, basin.wshd, to create a unique number for each cell in watershed boundary.
2	Number of cell into which it drains	Calculates by using cell number and flow direction within AGNPS-GRASS module.
3	SCS curve number	Determined by AGNPS-GRASS module by using hydrological soil group, landuse, management practice and hydrologic condition base on Runoff SCS Curve Number method (Mockus, 1972; 1985).
4	Average over land slope %	Determined by AGNPS-GRASS module by using neibourhood techinique for slope prediction (temp_slope_map) and if statement in the code. if landuse equal water or marsh average land slope = 0. If temp_slope_map equal 0, average land slope = 0.5 or average land slope = temp_slope_map / 10.0.
5	Slope shape factor	Set to 1
6	Average field slope length (feet)	Determined by AGNPS-GRASS module. It is not greater than 400 feet and calculation detail is in agnps_input.c.
7	Average channel slope (%)	Determined by AGNPS-GRASS module.
8	Average channel side slope (%)	Determined by AGNPS-GRASS module (rules_ch_side_slope.c) and input by the user if channel type <= 1.
9	Mannings roughness coefficient for channel	Determined by AGNPS-GRASS module (rules_man_n.c) depands on landuse condition.
10	Soil erodibility factor (K) from USLE	To be created by user, basin.K, base on Predicting Rainfall Erosion Losses – A Guide to Conservation Planning (Wischmeier and Smith, 1978).
11	Cropping factor (C) from USLE	To be created by user, basin.C, base on Predicting Rainfall Erosion Losses – A Guide to Conservation Planning (Wischmeier and Smith, 1978).
12	Practice factor (P) from USLE	To be created by user, basin.P, base on Predicting Rainfall Erosion Losses – A Guide to Conservation Planning (Wischmeier and Smith, 1978).
13	Surface condition constant (based on land use)	Determined by AGNPS-GRASS module (rules_sur_cond.c) depands on management practice, landuse and hydrolic condition.
14	Aspect (one of 8 directions indicating drainage from cell)	Input by user, basin.asp.100, depands on AGNPS format.
15	Soil texture (sand, silt, clay, peat)	Input by user, basin.soils or basin.sand and basin.clay.
16	Fertilization level (zero, low, medium, high)	Input by user, basin.nut.
17	Incorporation factor (% fertilizer left in top 1 cm of soil)	Determined by AGNPS-GRASS module (rules_fert_aval.c).
18	Point source indicator (indicates existence of a point source input within a cell)	Input by user via interative menu.
19	Gully source level (estimate of amount, tons, or gully erosion in a cell)	Input by user via interative menu (ptsrc_input()).
20	Chemical oxygen demand factor	Set to 0.
21	Impoundment factor (indicating presence of an impoundment terrace system within the cell)	Set to 0.
22	Channel indicator (indicating existence of a defined channel within a cell)	Input by user via interative menu.

Table 1 Parameter Generation in AGNPS-GRASS module (Modified Finn *et. al.*, 2002).

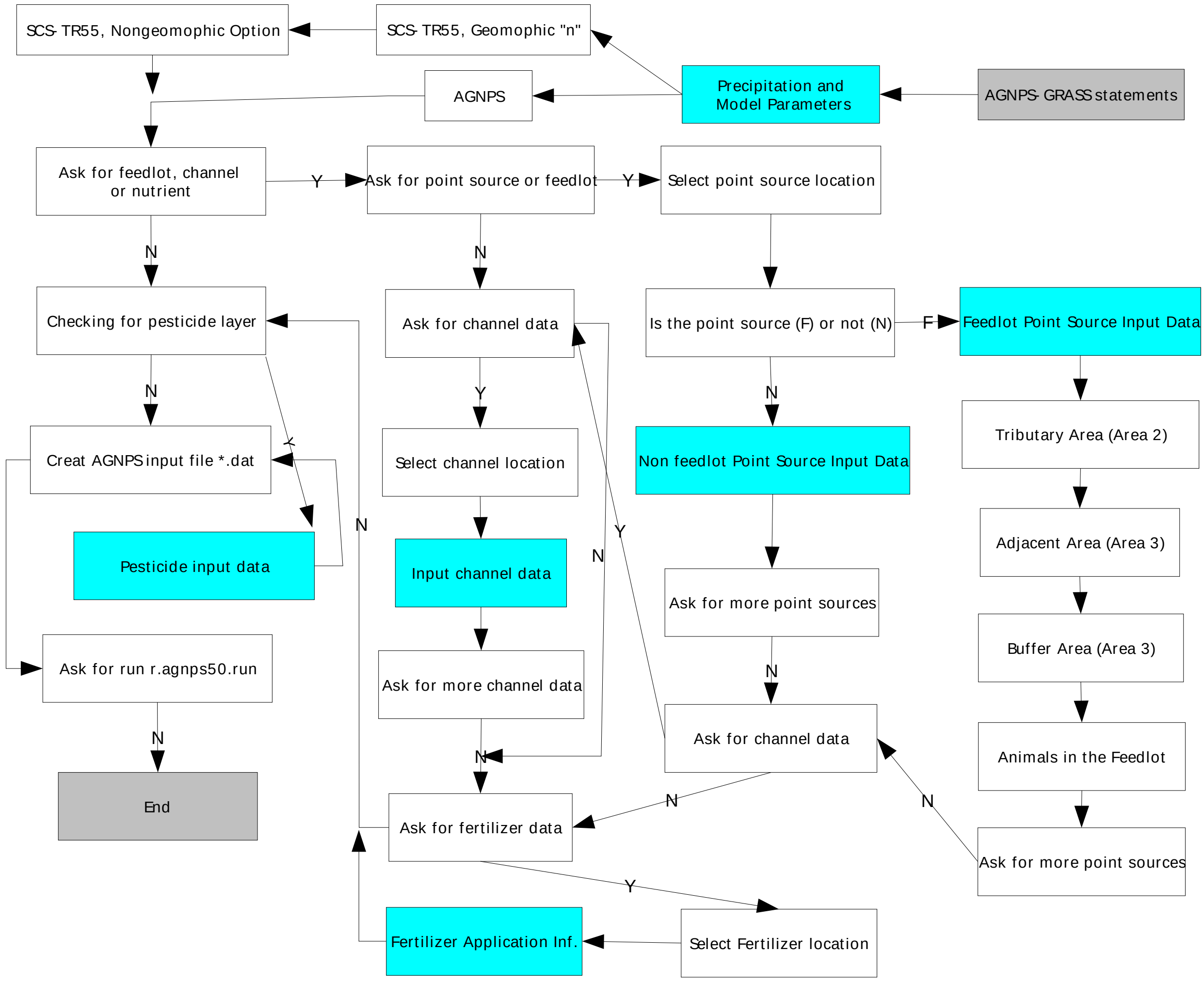


Figure 8 shows flow of input interface of **r.agnps50.input**.

The file basin.dat is passed to **r.agnps50.run** for calculation. Some flags need to be set for calculation output files. Table 2 shows the flags in **r.agnps50.run** module.

Num	**r.agnps50.run**	
	Flags	Describtionn
1	g	Create GIS formatted output file
2	a	Enable source accounting
3	s	Output sediment information
4	n	Output nutrient information
5	h	Output hydro information
6	d	Output debug information

Table 2 shows the flags in **r.agnps50.run** module.

The following files will be created by **r.agnps50.run**:- *basin.dep*, *basin.gis*, *basin.hyd*, *basin.imp*, *basin.nps* and *basin.src*. Only *basin.nps* is fed to **r.agnps50.view**.

After modification of AGNPS-GRASS module, as shown in Figure 5, the results can be seen in every options of **r.agnps50.view** menu. Figure 9 shows menu interface of **r.agnps50.view**. Sample output from options 2 and 9 is presented in Figure 10.

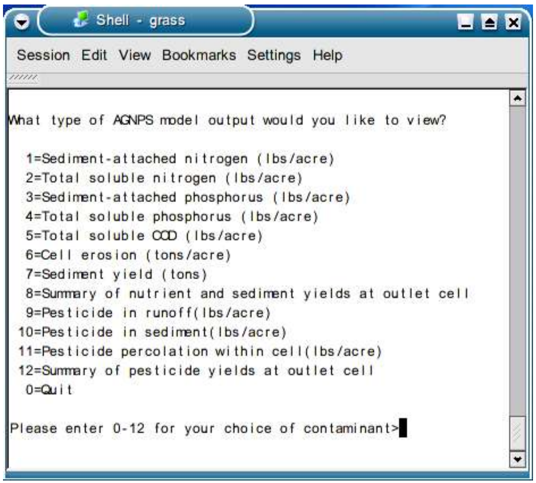


Figure 9 shows menu interface of **r.agnps50.view**.

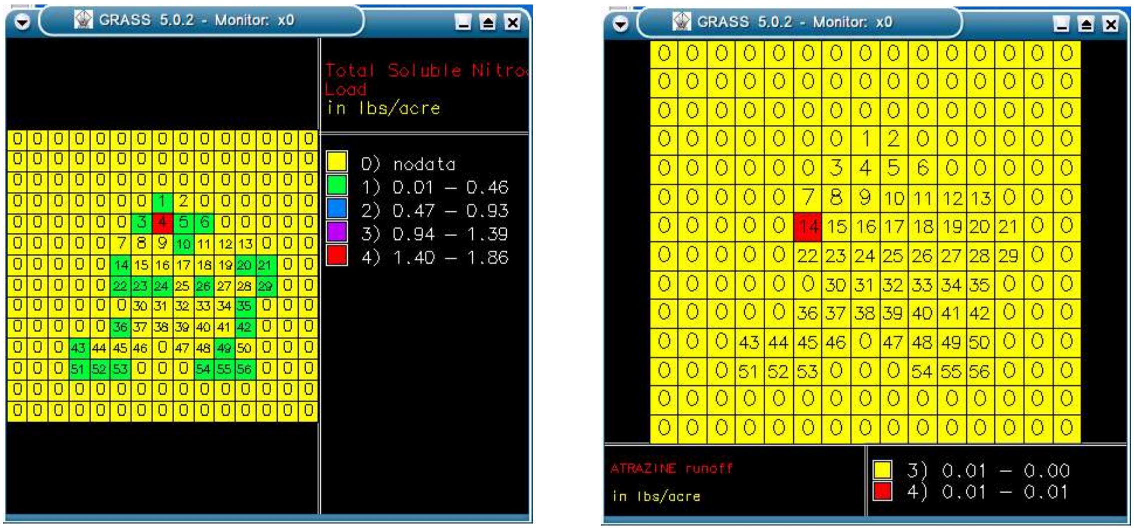


Figure 10 shows Total soluble introgen and Pesticide in runoff.

Suggested Developments to AGNPS-GRASS

Dunn and Hickey (1998) compared 4 methods of slope estimates within a GIS, neighbourhood method, quadratic surface method, maximum slope method and maximum downhill slope method. The local variability present in the DEM will be maintained by maximum downhill slope method without overestimating slopes. The AGNPS-GRASS module can improved by this slope calculation.

$$S = max \frac{(Z_9 - Z_i)}{L_c} 100 \qquad [1]$$

where
S = slope ratio in present
L_c = distance between neighbouring cell midpoints ($d\sqrt{2}$ for neightbours diagonally adjacent to the centre cell (Z_1, Z_3, Z_5 and Z_7)
i = cell number 1, 2, ..., 8

1	2	3
8	9	4
7	6	5

Figure 9 shows numbering in slope calculation.

Grunwald and Norton (2000) presented the method to calibration and validationthe a non-point source pollution model. They conclude that the surface runoff calculation by Lutz (1984) gives a better result than using the SCS-CN method after calibrated C_1 and C_3 . This can be applied to AGNPS-GRASS module.

$$I_a = 0.03\,S, \quad [2]$$

$$S = 25.4\left(\frac{10}{C} - 10\right), \quad [3]$$

$$a = C_1 e^{(-C_2/W_Z)} e^{(-C_3/Q_B)} e^{(-C_4 D)}, \quad [4]$$

$$Q_D = (P - I_a)C + \left[\frac{C}{a}\right]\left(e^{(-a(P-I_a))} - 1\right) \quad [5]$$

where

C = maximum discharge value (-)
S = potential maximum retention (mm)
a = factor of proportionality (1 mm^{-1})
C_1, C_2, C_3, C_4 = weighting parameters for optimization (calibration factors)
W_Z = week value (-)
Q_B = baseflow (l sec^{-1} km^{-2})
D = duration of precipitation (h)

The L and S factors in sediment discharge calculation are replaced with algorithems based on stream power thory.

$$f = \frac{A_{pwa}}{b l_{pwl}} \quad [6]$$

$$L_{sp} = \left(\frac{f l_{pwl}}{22.14}\right)^{0.4} \quad [7]$$

$$S_{sp} = \left(\sin\frac{S_x}{0.0896}\right)^{1.3} \quad [8]$$

where

f = form factor (-)
b = width of contour element (m)
A_{pwa} = partial watershed area (m^2) (the upslope area draining into each pixel)
l_{pwl} = partial watershed length (m) (the flow length draining into each pixel)
L_{sp} = L factor (stream power theory)
S_{sp} = S factor (stream power theory)
s_x = slope (^{o})

The coefficient of Nash and Stucliffe (1970) is introducted by Grunwald and Norton (2000) to measure a fit of actual and predicted data.

$$E = \frac{[\sum_{i=1}^{n}(m_i - \bar{m})^2 - \sum_{i=1}^{n}(p_i - m_i)^2]}{\sum_{i=1}^{n}(m_i - \bar{m})^2} \quad , \quad i = 1, 2, \ldots, n \qquad [9]$$

where
m_i = measured variable
p_i = predicted variable
$\bar{m}$ = arithmetic mean of m_i for all event $i = 1, 2, \ldots, n$

If predicted values are same as observations, E is equal 1. If E is low value, the deviations between measured and predicted values are high. If E is negative, predictions are very poor.

The user can modify "/src/raster/r.agnps50/agnps-source/ro.c" file to change the surface runoff calculation and "/src/raster/r.agnps50/agnps-source/xeros.c" file to change the sediment calculation.

Conclusions

The AGNPS-GRASS module is a complicated module; there is a large amount of code and not much documentation. This paper attempt to solve the problems that can be encountered by a novice user. However, the authors have still not examined all the AGNPS-GRASS code.

The following point have been noted for possible improvement
1) Allow Land slope shape code to have a value other than 1.
2) Allow AGNPS decay indicator to have a value other than 1, and Percent nitrogen, phosphorus and COD decay to be set to non-zero values.
3) Allow Hydrologic condition is set to values other than "good".
4) Allow input of subarea.
5) Provide documentation about the pesticide calculation.

For GRASS the developer should add more responsible to the code.
1) Guaranty the results of every module in the scope of developing.
2) Update text base help to graphic base help.
3) Add flow chart of module interface.
4) Improve GUI.
5) Develop a checking system to ensure correct operation after installing AGNPS-GRASS module.

Next study
1) Locate some of AGNPS data that can use to verify the AGNPS-GRASS module.
2) AGNPS-GRASS module should be improved.

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