Area Story

Sub-pixel de-composition technique (SP-DCT) for irrigated area Calculations

A sub-pixel de-composition technique (SPDT) was developed to determine sub-pixel areas (SPA) from the full pixel areas (FPA). Often, when a class is mapped and labeled such as "irrigated areas in command area" there is a tendency to think that every pixel within the class is fully irrigated. Indeed, that is how most areas are calculated!. But in reality, the pixels in the class only show FPAs. So when an area is calculated based on FPAs, it must be noted that only a certain fraction of FPA will belong to a particular land use. In the AVHRR 10-km, this issue becomes even more critical since every pixel encompasses 10,000 hectares. Each pixel will consist of numerous land use types and various percentages of land cover categories, but will have a composite name such as "irrigated areas: command area".

We begin the process of SPA calculations for irrigated areas, once the FPAs irrigated has been established. The 34 class map of the Global map of irrigated area (GMIA) presents the FPA pixel location and their spatial spread (see Figure A1). The sub-pixel areas (SPA) irrigated (or the percentage of actual area irrigated) is determined based on a unique approach of sub-pixel de-composition of FPAs.

The methodology and the processing steps involved in sub-pixel de-composition techniques are described below. In order to get greater precision in area calculations, we masked the AVHRR image areas for each of the 34 classes separately based on 3 seasons: (a) June-September, (b) October-February, and (c) March-May. For each class, the AVHRR band 1_{max} and AVHRR band 2_{max} were determined for each season. Then a class by class image analysis was conducted for determining areas. For example, start with class 1. The FPA spatial distribution around the World for class 1 is shown in Figure A2. The AVHRR spectral reflectivity for class 1 was computed for June-September taking: (i) AVHRR band 1_{max} and (ii) AVHRR band 2_{max}. This 2-band image of AVHRR band 1_{max} and AVHRR band 2_{max} encompassing the class 1 area was used to classify into 10 sub-classes of class 1. The distribution of the 10 sub-classes of class 1 is shown in Figure A3. The sub-class AVHRR band 1_{max} and AVHRR band 2_{max} values are then plotted onto 2-d feature space (2-d FS) plot (Figure A4) and the percent area irrigated is determined instantly from Figure A4 based on the location of the point falling on the 2-d FS sub-pixel de-composition plot (SP-DCP). Using the similar approach, each of the 34 irrigated area classes were classified into 10 sub-classes leading to a 340 discrete classes; each class with its own irrigated area percentage based on where it falls in 2-d FS SP-DCP. It is indeed, possible to plot every pixel in the GMIA onto 2-d FS SP-DCP and derive irrigated areas. But, our studies showed providing sufficient sub-classes would suffice and will capture most of the variability in areas from within a class.

The percentage irrigated areas provided in the SP-DCP plot were determined based on Described in documentation): (a) percent irrigated area canopy cover versus AVHRR 10-km band reflectivity and NDVI relationships from the Krishna and Ganges field work, (b) percent cover as in IWMI GT data of the World versus AVHRR 10-km NDVI or band

reflectivity, and (c) extensive literature review. Also theoretical evaluations of the brightness-greenness-wetness (BGW) 2d-FS (see Thenkabail et al. 2005) helped us assign irrigated area percentages with great degree of certainly. It must be noted that greater the understanding one has between the percent irrigated area vs. band reflectivity, greater the reliability of area calculations. This can come with greater intensity of field data, targeted for acquisitions during unique seasons. However, it must be stated that the level of understanding and the detail used in this study are the best available in the World at present.

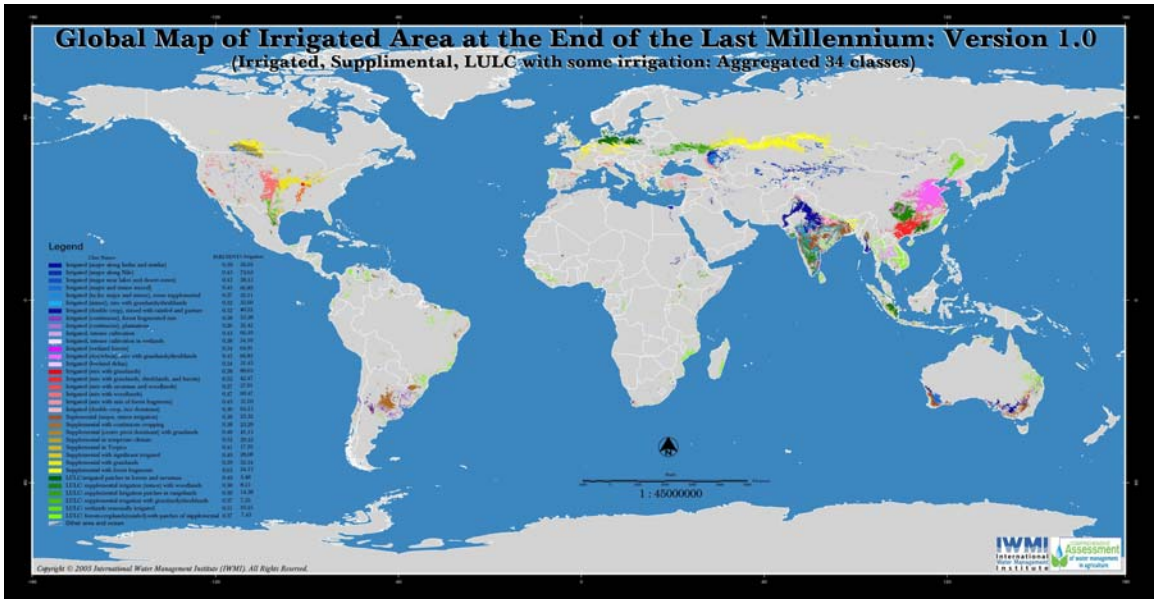

Figure A1. Spatial distribution of the 34 irrigated area classes in the World. The areas covered by these classes provide full pixel areas (FPAs). But the FPAs are NOT actual irrigated areas. The challenge is to determine the exact irrigated area within each pixel, which is done here through sub-pixel de-composition technique (SP-DCT).

The position in 2-d FS that a sub-class reflectivity of AVHRR band 1_{max} and AVHRR band 2_{max} falls helps determine percent area irrigated. The percent area irrigated shown in this plot were carefully established based on ground truth (GT) efforts in river basins, World, and from literature. Ten sub-classes of each of the 20 irrigated area classes, lead to 200 sub-classes. The percent area irrigated can be instantly picked up based on the point location of these 200 classes in 2-d FS brightness-greenness-wetness (BGW) plot.

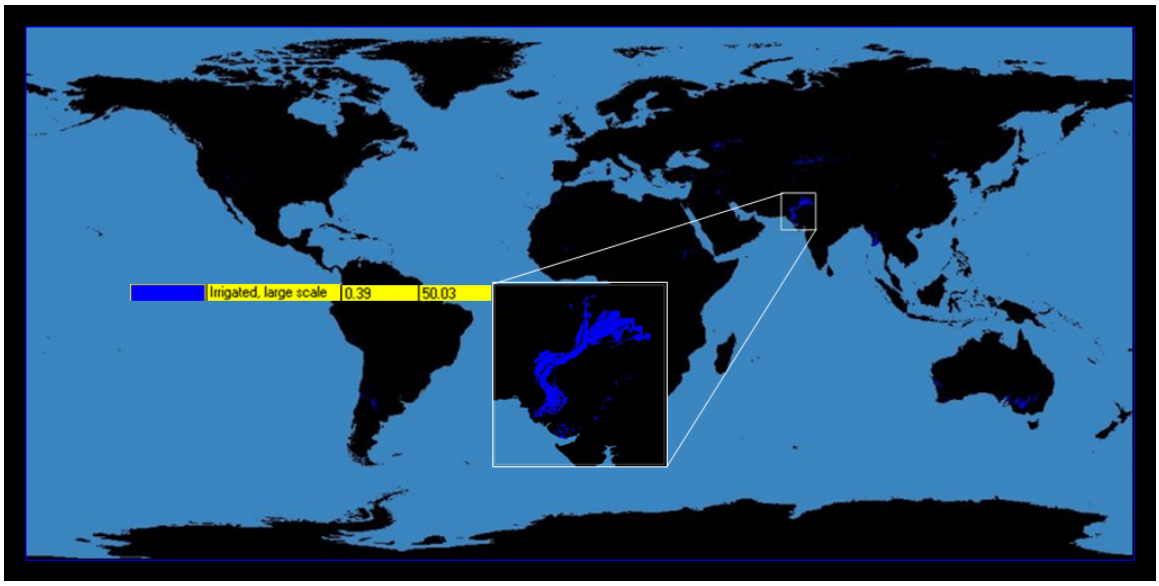

Figure A2. The spatial distribution of the full pixel area (FPA) of irrigated class 1 across the World. Based on class identification and labeling process, every pixel of class 1 is irrigated. But in reality, only a fraction of the pixels are irrigated at any given time of the year. The irrigated area can vary between 0 % (when fallow) to 100 % (during full canopy cover). Sub-pixel decomposition techniques (SP-DCT) were used to de-compose and determine the percent irrigated at a given time for each pixel.

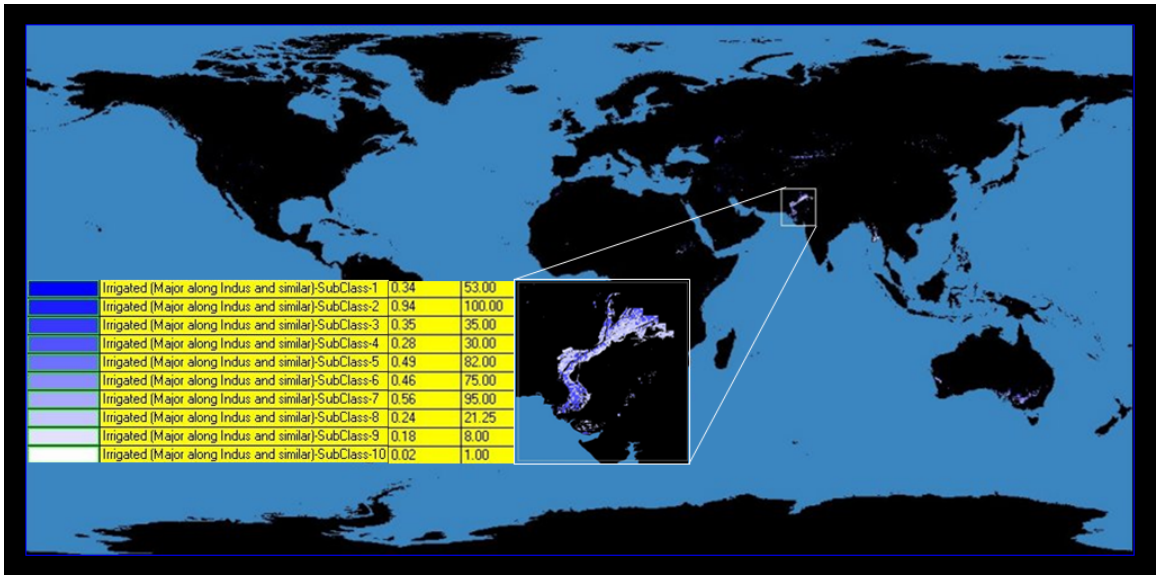

Figure A3. The 10 sub-classes within the irrigated area class # 1. Each irrigated area class was divided into 10 sub-classes to better estimate irrigated area percentages and their variability within a given class.

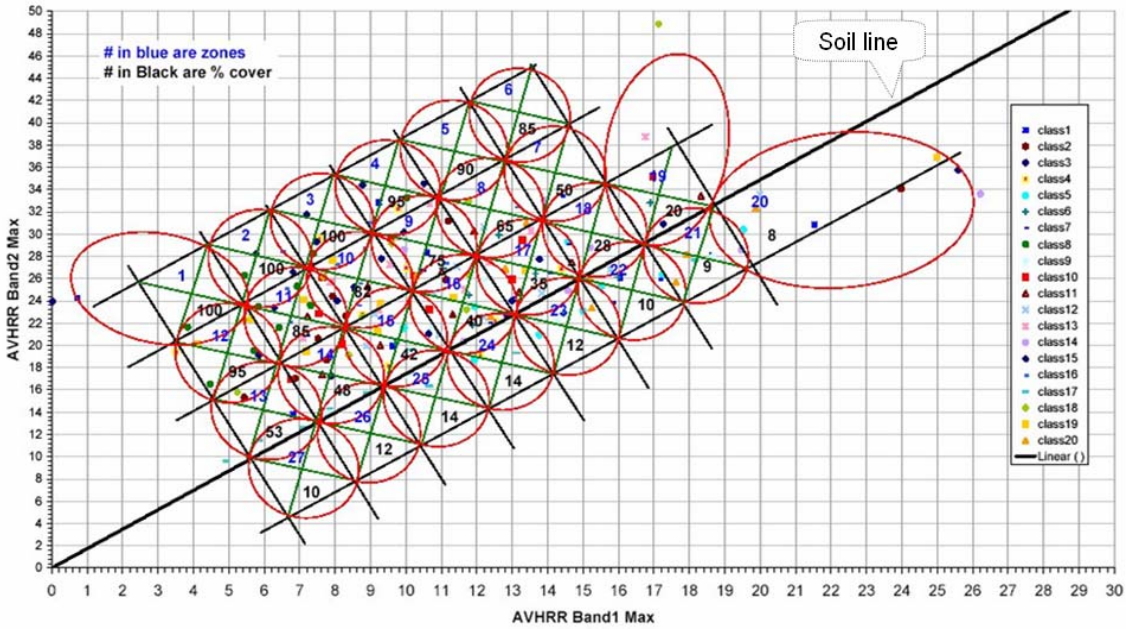

Figure A4. Sub-pixel de-composition technique (SP-DCT) for estimating irrigated areas in 2-dimensional feature space (2-d FS).

The research in sub-pixel decomposition techniques (SP-DCT) lead to a series of unique sub-pixel de-composition plots (SP-DCPs) (e.g., Figure A4). The characteristic SP-DCPs providing relationships between percent irrigated areas in a 2-d FS AVHRR band 1_{max} and AVHRR band 2_{max} were developed separately for irrigated, supplemental irrigated, and LULC classes with some irrigation. The unique relationships to derive percent irrigation from AVHRR band 1_{max} and AVHRR band 2_{max} were:

1. SP-DCT for irrigated area classes 1-20 (Figure A4);
2. SP-DCT for supplemental irrigated area classes (Figure A5a and A5b); and
3. SP-DCT for LULC classes with some irrigation (Figure A6a and A6b).

There were separate percent irrigated area sub-pixel de-composition plots (SP-DCPs)for supplemental irrigated area classes: (a) 21, 23, and 24 (Figure A5a), and (b) classes 22, 25 to 28 (Figure A5b). Similarly two SP-DCPs were developed for LULC classes with some irrigation (see Figure A6a and A6b). When we can not develop single SP-DCPs for all classes, we will need to have separate plots for unique set of classes. If a unique relationship is required for sub-classes of a single class that too will need to be developed. Indeed, with grater filed data and experience, the percent irrigated area estimates can be improved significantly if we can come up with 34 SP-DCPs, one for each class.

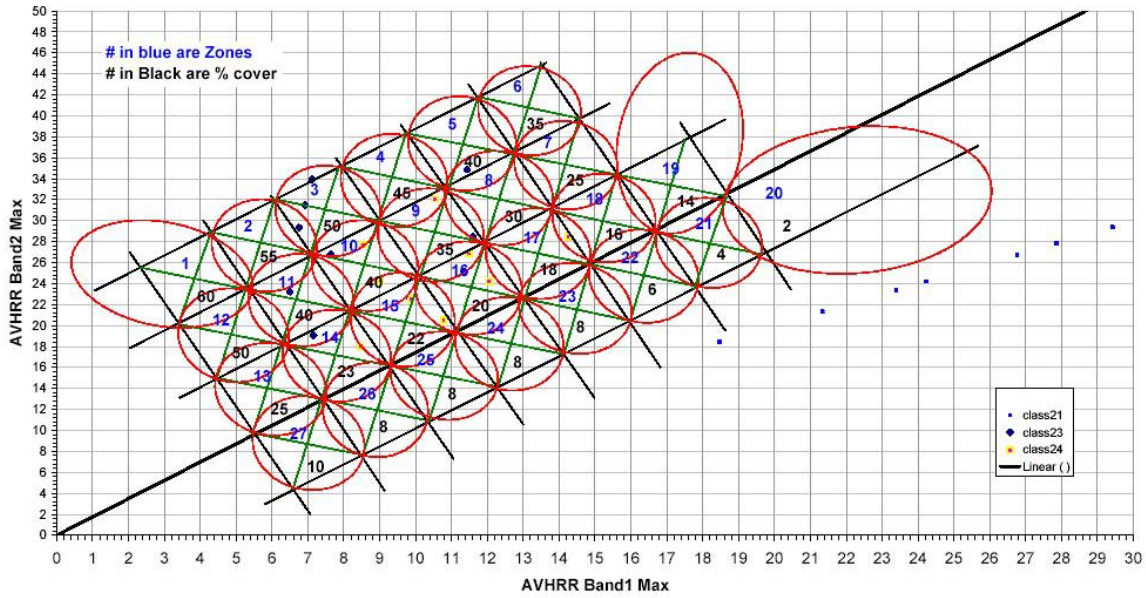

Figure A5. Sub-pixel de-composition technique (SP-DCT) for estimating supplemental irrigated areas (classes 21, 23, and 24) in 2-dimensional feature space (2-d FS). The position in 2-d FS that a sub-class reflectivity of AVHRR band 1_{max} and AVHRR band 2_{max} falls helps determine percent area irrigated. The percent area irrigated shown in this plot were carefully established based on ground truth (GT) efforts in river basins, World, and from literature.

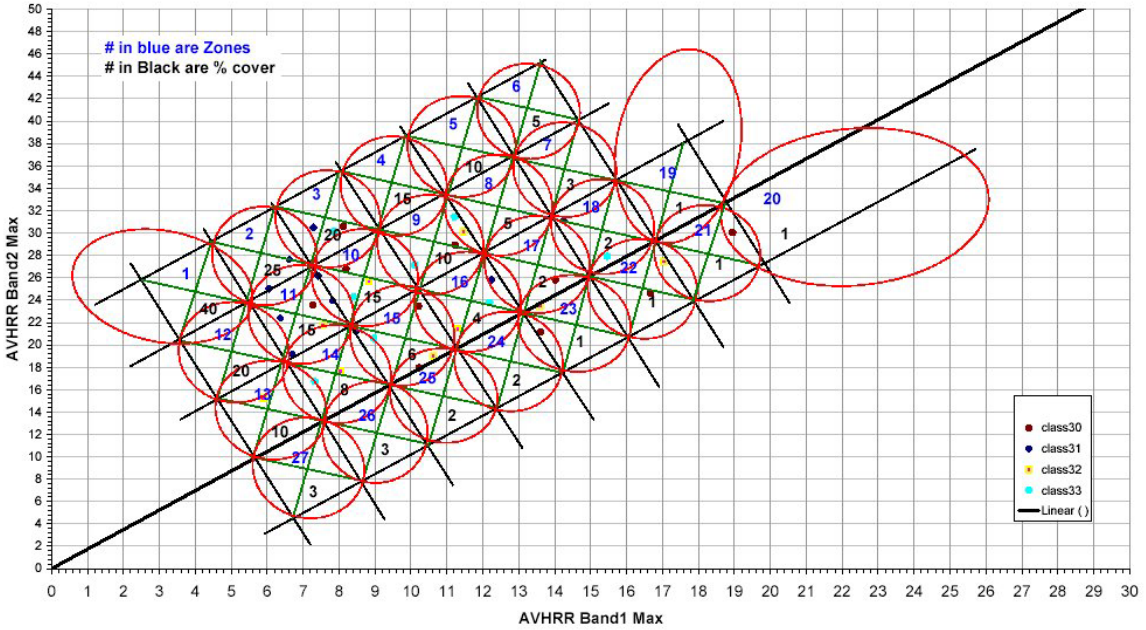

Figure A6. Sub-pixel de-composition technique (SP-DCT) for estimating LULC classes with some fragmented irrigation (classes 30 to 33) in 2-dimensional feature space (2-d FS). The position in 2-d FS that a sub-class reflectivity of AVHRR band 1_{max} and AVHRR band 2_{max} falls helps determine percent area irrigated. The percent area irrigated shown in this plot were carefully established based on ground truth (GT) efforts in river basins, World, and from literature.

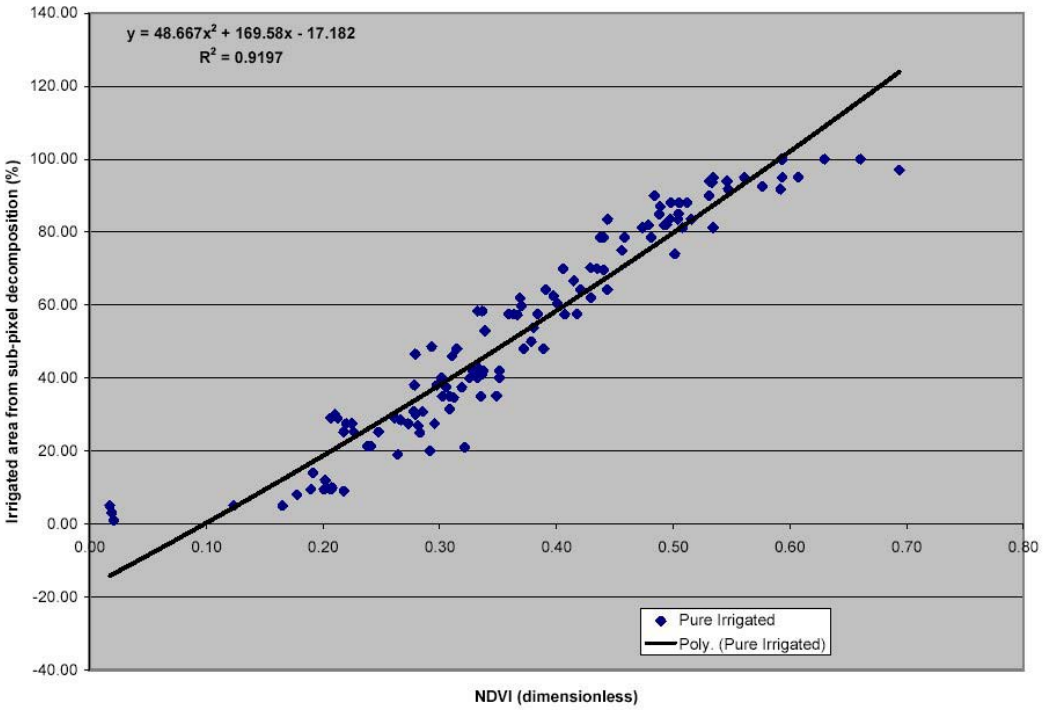

Figure A7. Relationship between percent irrigated area of class 1-20 and the AVHRR NDVI computed using band 1_{max} and AVHRR band 2_{max} reflectivity. The final relationship between the percent irrigated areas of class 1 to 20 and their NDVI computed from **band 1_{max} and AVHRR band 2_{max} reflectivity.**

The percent irrigated areas estimated for 200 sub-classes of class 1 to 20 are related to NDVI computed from the AVHRR band 1_{max} and AVHRR band 2_{max} for each of the 200 classes (see Figure A4). Based on the extensive data used and sophisticated approaches adopted, the relationship provides a robust and rigorous relationship to determine percent irrigated based on NDVI computed from the AVHRR band 1_{max} and AVHRR band 2_{max}.

The SP-DCT for irrigated area estimation has many unique advantages. These are listed below:

1. **Advanced, automated and logical**

Every sub-class (or for that matter every pixel) within a class falls in a 2-d FS that instantly provides a percent cover irrigated based on SP-DCT. The approach is robust and can not go wrong since it is based on solid first-principles. The approach used in this study for area calculations is unique and is applied for the first time in the study of this scale. It is fairly automated (e.g., involves picking % irrigation instantly based on where the point falls in AVHRR band 1_{max} and AVHRR band 2_{max} SP-DCPs) and is logical and straightforward.

2. Area at any time of the year

This is the first study that allows area calculations at any time of the year. We have reported areas for different seasons (see section #). But the Figure m32 through m34 can be used to calculate irrigated areas during any month.

3. Adjustable in the future

If for example, let us hypothesize that the percent irrigation is either slightly over-estimated or slightly under-estimated as a result of pooling large number of classes into a single SP-DCP (e.g., Figure m32). So, if separate relationships are developed to estimate percent irrigated areas for sub-classes of each of the 20 classes based on separate class by class AVHRR band 1_{max} and AVHRR band 2_{max} SP-DCPs. This may help provide better estimates of irrigated areas within a class. But, the advantage this study provides is that if and when more rigorous field data are available in the future, the knowledge can be easily applied to the IWMI-GMIA maps and images to check present estimates of area calculations and help in any adjustments that may be required with very little effort;

4. Improvements at local or global level

The SP-DCPs are built in such a way that they can be easily modified at local, regional, National, and Global levels using additional data that maybe available at present or at some time in the future. For example, if some user has extensive field data for a particular Nation then they can build their own percent irrigated on. AVHRR band 1_{max} and AVHRR band 2_{max} SP-DCPs.