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DETECTION OF BIOMASS BY AN EMPIRIC ALBEDO AND SPECTRAL REFLECTANCE MODEL IN THE SAHARA DESERT FROM LANDSAT-IMAGERY

MICHAELA C. MUEKSCH

Bonn University
Caecilienstr. 6a
WEST GERMANY, F.R.G.

ABSTRACT

Multitemporal observations of vegetation situation is important for the assessment of dry and semi-dry areas to plan further measures of afforestation,irrigation and prediction of climatological developments in respect to the survival of people living in those areas.

Ground truth missions for this purpose are bound to high costs and therefore ways of minimising and avoiding these expenses have to be studied. In desert regions such ground truth missions can cause further problems.

An empiric method of quantification and prediction of global biomass change in a coast-desert region of Tunesia by albedo and spectral reflectances without ground touch is presented.

Albedo and spectral reflectances are calculated from photometric data in a model regarding the main influences from sky,sun irradiance and atmospherical attenuation.

Data from a summer and winter situation are compared by a simple averaging,weighted by a compression of data distribution gained from a point operation procedure.

The results show a nearly 20% gain in biomass change,if a point operation for contrast enhancement of photometrically gained data sets is applied,instead of a simple averaging.

This procedure is applicable as long as a higher accuracy is not required and the changes and not the absolute values are demanded,because the reflectance references are estimated.

I. INTRODUCTION

LANDSAT-images in a digital form are only available for very few areas in the world,compared with the total coverage. Specifically in tropical regions and others,where military bases and movements are existing,CCTs are scarcely available. If one would only make use of digital data together with their expensive equipments and peripheries it would limit the applicability of images to some industrialised countries and some others on the upswing.

The majority of the developing countries would be extremely excluded and studies of surface structure,clima,ecology would never get any importance. Permanent,inexpensive and small scale monitoring of large tropical zones are still out of discussion and it seems,that the digital analysis techniques and rapid computer developments are attracting more and more researchers for methodological research. Remote sensing is in danger to loose the base for servicing human demands as a contribution to rescue the poor,famine and death threatened majority of this planet and perverts to tools for selfishness,carriers,opportunistic aims, uncritical positivism and war purposes.

Therefore those with responsibilities to the majority of poors and less fortunate people should create ways and methods,sometimes simple and modest to gain data of dryness,flood,degradation of threatened regions to analyse,predict and warn governments to take appropriate measures for their people.

Machine processing for example offers a large variety of techniques,originally bound to digital processing,but which can be modified for purposes in small scale,non sophisticated evaluation and monitoring without loosing its connection to methodology and helps at the same time fulfilling the moral commitments of remote sensing.

Such a method of machine processing is described here,modified and applied on a multitemporal monitoring model of albedo and spectral reflectances in desert regions to detect biomass and its changes without ground truth,neither by expensive terrestrial nor airborne observations.

II. TECHNIQUE OF DATA GAIN

The data have been gained by photometric measurements in connection with a photometer,an amplifier and an A/D-converter coupled to a personel computer. The maximum of the spectral sensitivity of the photodiode was in the midth of the 4 LANDSAT-bands. The images were positive prints of 1:500 000 and 1:250 000 scale of band 5 and 6.

After delineating the different contrast regions(Figure 1-4),measurement points were positioned on transparencies over the images by numbering them consecutively.

Point by point was measured with the photometer over a strong and voltage stabilised constant light spot on a opaque screen of a light box.

Before and after the measurements the voltage signals of the grey level scale at the foot of the image were associated to the range between a minumum and maximum assumed reflection of brightest and darkest areas and estimation of reflection range.

Non-linearities of the calibration function were eliminated by decalibration through a point operation which will be described theoretically below.

The original gray scale transformation was proportional in a certain range of gray level values. The accuracy range could be a priori fixed to 10% reliability,a demand given. Higher demands would not have been appropriate to the measuring device.

Values were reduced by time dependant dark current variations between starting and end calibration. Sample checks were switched in between the measurements to control the dark current development. It was linear by decreasing within a range of one hour.After one hour the calibration was started again for the next hour set.Approximately 300 values could be gained within 4 hours.

III. REDUCTION OF ALBEDO AND SPECTRAL REFLECTANCE

The atmospherical effects have a great impact on reflections in desert regions. Passengers flying from Europe south over the Sahara desert recognize the haze and dust layers over large areas even during sunshine and clear weather conditions. Exstinction is quite high.

Even during clear sky conditions the backscattering effects of light at particles can be "seen" as a turbid atmosphere. Satellite images show similar phenomenons,especially during summer.

These effects have to be eliminated,as far as possible under the assumption of known empiric formulas and models,because less information is known from the atmosphere and its behavior in the Sahara desert.

The first influence is given by the atmospherical transmission:

$$\tau_A = e^{-\tau' \sec\theta} \qquad (1)$$

with θ = zenith angle of satellite,D = distance to nadir point, H = satellite height:

$$\theta = \arctan\,(D/H) \qquad (2)$$

and

$$\tau' = 7.994 \cdot e^{-0.004\,\lambda} \qquad (3)$$

a simplified equation(Manual of Remote Sensing, 1975,p.190,Fig.5-6)

The total spectral irradiance is:

$$E = 2.0 \cdot \cos\theta_o \cdot e^{-\tau' \sec\theta} + 3.0 \qquad (4)$$

in which 2.0 is the monochromatic solar constant, θ_o = zenith angle of the sun and 3.0 is the sky irradiance at 10^h UT during the satellite transit.

The upward scattered radiance is:

$$N_A = 0.462 \cdot e^{-0.001\,\lambda} \qquad (5)$$

With the measured values in volts reduced with the photometrically decalibrated calibration function,reflections are simulated by Monte Carlo procedure and with a constant value for the attenuation coefficient(aerosol influence) for dust over deserts,related from a numerical integration up to 70 km altitude by 0.1231,an approximated radiance at the satellite sensor:

$$N_{sat} = R - R \cdot 0.1231 \qquad (6)$$

is obtained.

From this equation a spectral reflectance is finally found by:

$$\rho = \pi\,(N_{Sat} - N_A)\,/\,E \cdot \tau_A \qquad (7)$$

IV. THEORY OF POINT OPERATION IN APPLICATION TO MULTITEMPORAL OBSERVED REFLECTANCES

Point operations present a simple way of nonspatial image processing,modifying an output image according to its input image. Point operations are the basis for simple enhancements,gray scale transformations,decalibrations and others to get a quick impression of a feature or object status.

Analogously they can also be used for each compression or stretching of data sets,being spatially invariant.

The idea of application of point operation on multitemporal observations of albedo and spectral reflectances is based on the fact that after atmospheric reductions the results are not immediately comparable.

Reflectances during lower sun altidudes are smaller than during higher ones. The contrasts are stronger during lower altitudes,as shorter wavelength are absorbed by the atmosphere,the object appears darker and the shades becoming longer.

All these are well known phenomenons which can be powerfully eliminated by digital image processing methods. But images in analog form presents problems,if there is no digitizing or scanning device available.

The only way remains in a reduction of the results point by point either by compression or stretching.

In the actual case of observing reflectances on two images from June 1975 and December 1975 in Tunesia,a summer and winter scene of vegetation is presented.

Biomass is decreasing from coast to inland and then to Sahara desert in summer,because of drying out process. In winter the biomass is enlarged also by rainfalls into the desert. The changes on the images are obvious(Figure 1,3).

After a reduction of the values it seems that there is a constant difference valid for all reflectances. The easiest way of comparison is to take the arithmetic mean of the differences and get a computed summer reflectance. The difference between the computed and observed summer reflectance would be the change or indication of change.

But some values are differing strongly from the mean which indicate very significant changes. They are influencing the mean by causing a higher standard error in such a way that the changes may fall within this error range and no significance is given any longer.

The only way is to compress the larger differences and contrasting the calculated values against the observed ones and get a much more reliable tendency of change.

For an absolute value determination ground measurements have to be carried out before the reductions which were not given in this case.

Applying a point operation for data compression the winter reflectances formed the input histogram H_w. An arbitrary summer value expressed by a winter one is:

$$\rho_s = f(\rho_w) \qquad (8)$$

Under the assumption that the function is monotonically increasing with finite slope the inverse is:

$$\rho_w = f^{-1}(\rho_s) \qquad (9)$$

This is called here "the reflectance transformation function" at which the input reflectance histogram H_w is reflected to derive an output reflectance histogram H_s. This histogram is not the one of the original summer reflectances.

The integral of input histogram H_w equals to that of the output histogram H_s:

$$\int_{\rho_s}^{\rho_s+\Delta\rho_s} H_s \cdot d\,\rho_s = \int_{\rho_w}^{\rho_w+\Delta\rho_w} H_w \cdot d\,\rho_w \qquad (10)$$

As the histogram are infinitesimally represented by rectangular approximation,the integrals equals also in the way,that:

$$H_s \cdot \Delta\rho_s = H_w \cdot \Delta\rho_w \qquad (11)$$

Solved to H_s one obtains:

$$H_s = H_w / (\Delta\rho_s / \Delta\rho_w) \qquad (12)$$

and with transition to the differential quotient:

$$H_s = H_w / (\partial\rho_s / \partial\rho_w) \qquad (13)$$

as ρ_s is given by (8) a substitution gives:

$$H_s = H_w / (\partial / \partial\rho_w) f(\rho_w) \qquad (14)$$

A free change of variables yields the output histogram:

$$H_s = H_w(f^{-1}(\rho_s)/(\partial f / \partial\rho_s) \qquad (15)$$

The peek of this histogram is set to the weight p=1.
Then the above mentioned reflectance differences from the observations between summer and winter are formed,their arithmetic mean is calculated added to the different winter reflections and this value is multiplied by the current weights from the output histogram of the corresponding winter reflections. The expression is:

$$\rho_{cs} = \left(\frac{\Sigma(\rho_s - \rho_w)}{n} + \rho_w \right) \cdot p \qquad (16)$$

These computed values result in a compression, expressed by a lower standard error.

V. THE ACTUAL MODEL AND ITS RESULTS

The input histogram analysis of the winter reflectances show that the values are distributed by a binomial distribution with the peek shifted into the positive direction.

As the number of observations is high,the binomial distribution can be replaced without loss of accuracy by a simplified Gauss function of the form:

$$H_w = e^{-(\rho_w - c_p)^2} \qquad (17)$$

with p_H as the peek ordinate of H_w and c_p as the abszissa of it(Figure 8.).

Thus with the inverted linear reflectance transformation function,substituded into (15) yields:

$$H_s = 1/a \; H_w \cdot ((\rho_w - b)/a) \qquad (18)$$

A substitution of (17) into this equation gives the output reflectance histogram:

$$H_s = 1/a \cdot e^{-k^2} \qquad (19)$$

with:

$$k = 1/a(\rho_w - b) - c_p \qquad (20)$$

The maximum of the distribution of 50 winter reflectances was lying at 3.5% with a cumulative point of 47% frequency distribution(Figure 7.).

The linear reflectance transformation function (Figure 6.) had the linear parameters of $a = 0.1231$ and $b = 3.1482 \; 10^{-4}$ with a correlation coefficient of $r = 0.675$ and a standard error of 18%.

A non-linear transformation by a potential function gave no significant better results. If one would have used the original winter reflectance distribution (Figure 8.),set to unity in the Gauss-distribution and related the weights from this function,the effects would have not been as compressing as from the output histogram of the point operation procedure (Figure 9.).

The total procedure was carried out in a program in comparing the changes of reflectances from the unweighted values over the arithmetic mean with those of the weighted ones from the point operation.

Approximately additional 22% biomass changes could be detected by the point operation.

The total change of biomass was 83% from summer to winter. This means,that the observed area will be green in the winter time which can be stated from ground observations. But the value of 83% can never be accepted as an absolute value.It gives a tendency aiming to that value. A value of 50% can be accepted as an absolute value and it is higly probable that this one will not be falling below 50% (Figure 10,11). The absolute amount in a single change was lying at 15% in average.

In a second case of two summer and winter reflectances there were 0% of all over change,as very small changes in hazy and dust influenced images are not detectable with this method.

If the spectral reflectance transformation function is showing a very low significance or correlation coefficient,a point operation is without success. In this case other methods have to be applied.

VI. CONCLUSIONS

Measurements of albedo and spectral reflectances on photographic products of LANDSAT-scenes by inexpensive photometric devices and reduction by simplified atmospheric,sun and sky irradiance models lead to reasonable results in case of use as comparison values for multitemporal analysis, detecting all over surface changes,i.e. preferably biomass.

By a compression with a point operation procedure,calculated reflectances are getting higher compactness and surface changes,due to other originally observed reflectances,are protruding stronger than by simple averaging.

Each visual change has to be carefully studied from the particular reflectance value. The analysis also limits the application to clear images. If the desert especially in summer,when the dust is carried by the winds and the scene is looking hazy and veiling,there will be less chance for an acceptable result.

A visual difference has not necessarily be a real difference,as effects from photographic process,grain influences and other descrete sources can falsify the impression.

Finally here as in other applications of machine processing principles ,the rule is that an output image can only be as good as an input image is. Therefore the quality of the image has to investigated before the application of such a method of machine processing.

VII. ACKNOWLEDGEMENTS

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AUTHOR BIOGRAPHICAL DATA

Michaela C. Mueksch,born in 1942,studied geosciences and astronomy at University of Bonn,F.R.G. from 1964 to 1969,MSc. in geodesy and Phd. in geosciences,
several years working in surveying and photogrammetry of Civil Service and industry,research in application of GIS in urban and regional planning and thematic mapping on computer basis from 1973 to 1975,lectures and researches in photogrammetry, cartography and remote sensing in West Africa(Cameroon) and East Africa(Tanzania) from 1976 to 1982,since 1976 she is working on remote sensing applications in ecological monitoring of tropical zones and since 1983 in software developments for computergraphics,automatic cartography,image interpretation and processing on low cost basis and equipment,
she has published more than 20 articles and papers, member of ASP(American Society of Photogrammetry) and DGPF(Deutsche Gesellschaft für Photogrammetrie und Fernerkundung)

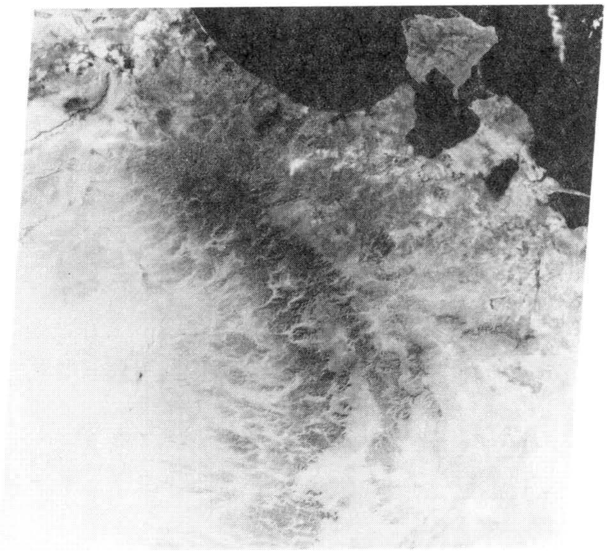

Figure 1. Winter scene from Tunesia on the 12/26/75

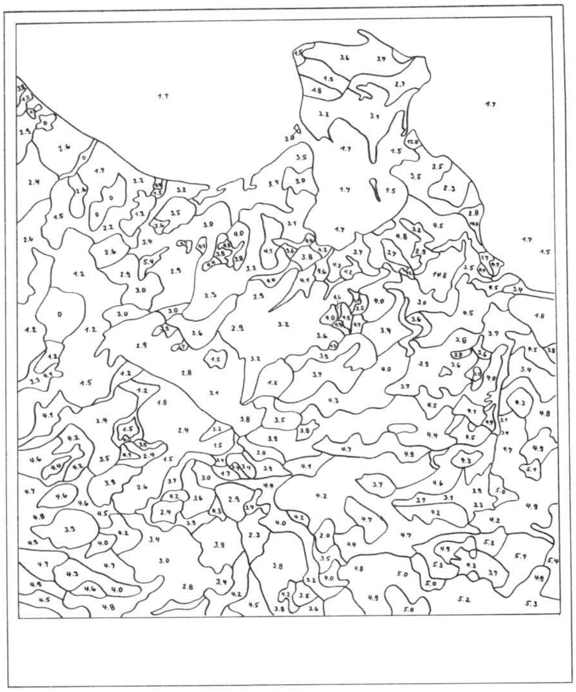

Figure 2. Visually delineated reflectance areas for the winter scene

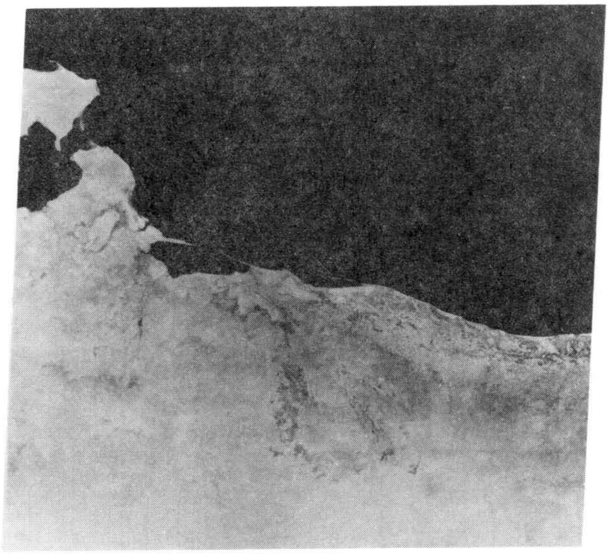

Figure 3. Summer scene from Tunesia on the 6/28/75

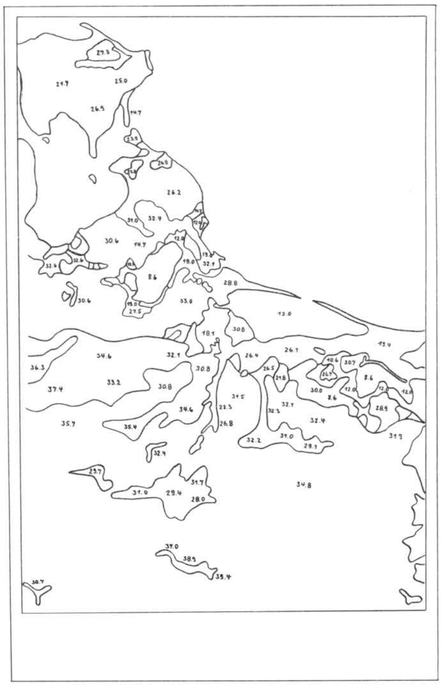

Figure 4. Visually delineated reflectance areas for the summer scene

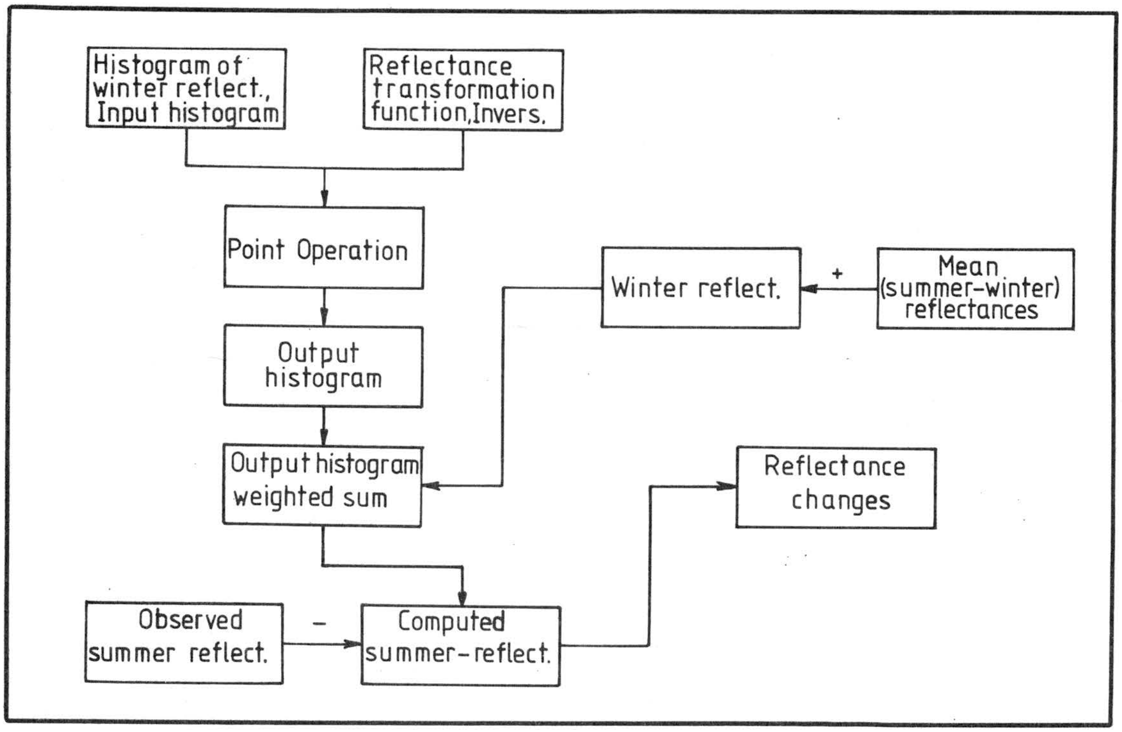

Figure 5. Multitemporal albedo and spectral reflectance reduction procedure

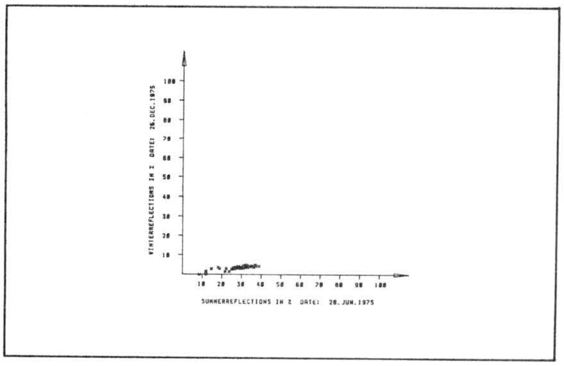

Figure 6. Reflectance transformation function

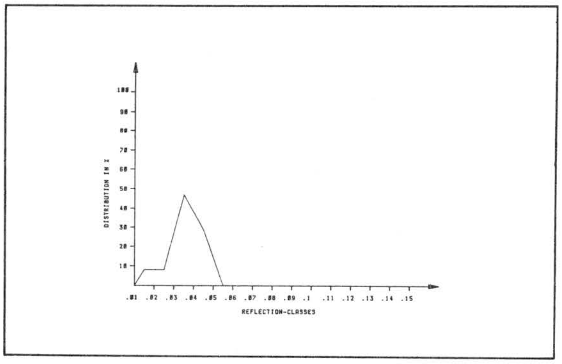

Figure 7. Distribution of winter reflectances

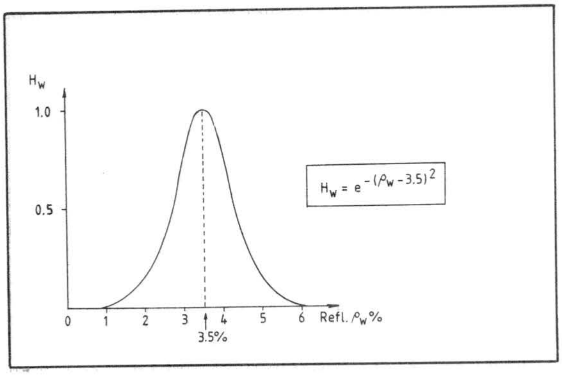

Figure 8. Gaussian input histogram H_W before point operation

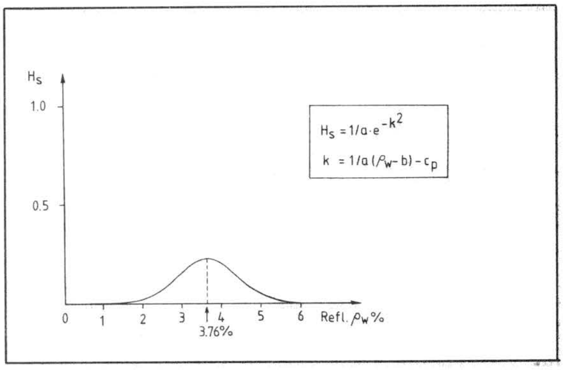

Figure 9. Gaussian output histogram H_s after point operation (larger and smaller reflectances have lower weights)

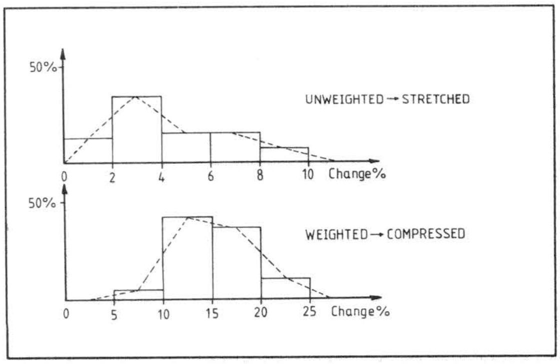

Figure 10. Distribution of change by unweighted mean

Figure 11. Distribution of change by "point operation" weighted mean