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TRAINING AND EDUCATION IN REMOTE SENSING APPLICATION IN HYDROLOGY

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ABSTRACT

Water resources development is of vital importance for rapid economic stride, social progress and overall improvement of quality of life of people. Alongwith the national priority of implementing water resources development programs, human resources development in this sector needs special emphasis, because of 'new technologies' increasingly being available to solve highly complex and challenging water resources assessment, development and management issues. Space technology is proving new ways to reorient our philosophy and practice in Water Science that was never visualised two decades ago. Training & education would play a key role to understand 'hydrology' and 'hydrologic remote sensing' and its transformation into water resources development. In this paper, need, concept, curriculum, Indian scenario, in 'training & education in remote sensing in hydrology" is revisited with a view to emphasize, shape and reorient our philosophy & practice in this emerging learning era.

1. HYDROLOGY AS AN APPLIED AND MULTIDISCIPLINARY SCIENCE

The inderdisciplinary approach to the problem of designing, operating and forecasting the water demands and the needs of our modern society has focussed on the subject, termed as "water resources engineering". However, basic to the subject of water resources is the "science of hydrology". Without the quantitative knowledge of hydrologic proccesses, the analysis of water resources problems such as water pollution & sediment transport can only be subjective. Hydrology as a science has grown and influenced by other disciplines, derived much strength from such subjects as physics, meteorology, oceanography, geology, geography, biology, agriculture forestry, hydraulics statistics & probability theory. In the modern period of hydrology, as in almost all natural sciences, the importance of social science disciplines (economics, political science, social science) has become evident as the society has become much more close and complex than ever before.

Hydrology is also basically an interpretative science, because of much of uncertainty provided by 'Nature'. To understand hydrology requires good instrumented data and physical observation about various hydrologic, hydrometeorologic, hydro- geologic, topographic, vegetation and environmental parameters and attributes, both historic as well as present. Again such huge amount of data need to be stored, manipulated and analysed for hydrologic modelling for prediction and forecasting. From 1950s and 1970s onwards, two revolutions: (i) advent of computer era for fast and economic data processing, (ii) advent of satellite remote sensing era for holistic view of the earth have made things easier and meet more or less the general needs of the hydrologists.

Like many tools available and being used by the hydrologists, remote sensing is another additional tool. Its strength lies in repeated and geographic-wide data acquisition techniques from orbital satellite altitude, data processing through optical instruments and in digital computer environment and 'integral nature of the study' never

offered by any tools before. Understanding 'hydrology' and 'hydrologic remote sensing' thus has become our priority to transfer the benefit of this modern technology to the humankind.

II. NEED DRIVEN REMOTE SENSING TRAINING & EDUCATION IN HYDROLOGY

Question obviously arises, where do we go from here? Answers lies in fixing our priority in water resources in national context and then through human resources development to achieve our goal.

Water resources development is essential for economic and social progress of humankind. Rapid population growth and desire for betterment of living standards in most under-developed and developing countries have resulted in sharp rise in human requirement of water, necessitating expeditious development of the available water resources and their proper management. Suitable technologies thus are needed to be evolved in different hydrologic regions for augmenting water resources to cater to the needs of areas with inadequate water supplies.

National priorities of water resources development in many countries are generally addressed to (i) harnessing water resources in water scarcity areas, (ii) cleaning pollution in major rivers, (iii) combating duel problem of flood and drought, (iv) hydro-power development in remote river valleys, (v) arresting siltation of reservoirs, (vi) environmental protection, (vii) irrigation command area development, (viii) assuring drinking water supply to urban and rural population, and (ix) an ever increasing water role to support agricultural production.

Most critical problems faced in water resources sector in (a) planning and investigation phase, (b) implementation & development phase, and (c) in post-development monitoring & management phase are the time-specific and site specific hydrologic (physical and environmental) data which are constrained by the inadequate in-situ hydrologic measurements or local observations. With the advent of orbital satellite remote sensing techniques with synoptic view over wide geographic coverage and many times a year, local, regional, national hydrology & water resources organisations in many countries have started gearing up to use this modern technology to supplement ground-efforts in water resources programs.

Large-scale operational use of remote sensing techniques in water resources planning would, however, require at the first instance, human resources development in water resources organisations through (a) in-service training and reorientation programs and (b) availability of trained/educated engineers and scientists coming out of the universities in the job market. It is realised by now, that, rapid advancement & realisation of an organisations goal depends much on trained & skilled manpower.

Well-trained and educated manpower in fundamentally remote sensing technology-based organisations as well as in academic institutes are also required to pursue research & generation of case studies towards operational scale applications in hydrology, since the technology is new, but at the same time, advancing fast offering new opportunities in hydrology and water resources.

III. CONCEPT OF TRAINING & EDUCATION : REMOTE SENSING TECHNOLOGY CONTEXT

It is an acceptable fact that scientific and systematic development of any natural resources is a function of multitude of factors & processes involved which an organisation need to look into with ultimate benefit to the users. Training and education are one amongst the crucial and major factors which organisations and nation have to develop in order to accelerate the development process in right direction.

Training can be conceptualised in general as the process of development and application of knowledge, skill and aptitude needed to improve individual's ability to solve production oriented problems and adapting improved practice and technique or skill at field level. Thus, training provides an individual with the improved knowledge and skill necessary to carry out specific work or task for betterment of his performance on job and is, therefore, essentially practical and job oriented.

In contrast, education imparts theoretical and conceptual knowledge aimed at stimulating an individual's analytical and intellectual facul-

ties not always bounded by few tools, methods and specific set of instructions. Thus, education offers a much wider horizon of knowledge than training. In short, training is oriented towards development of skill for professionals in the field while education imparts to more of knowledge and understanding at the foundation level of an individual. They are, however, complementary part of the same process of learning.

Remote sensing technology and applications, as it develops today, and as the new technologies are coming up in foreseeable future, encompasses a wide spectrum of higher learning and practicing tools, which in turn requires both training and education at different levels of developing professional skills and academic foundation.

Fundamental criteria for assimilation of remote sensing techniques in main-stream water sciences and engineering disciplines are:

- a strong foundation & knowledge about the subjects of hydrology and water resources.

- a strong far-sight & selectivity of approach as to how & where this technique can be judiciously applied so as to find solution to a particular problem with economics of scale and accuracy and cost-benefit aspects.

- since hydrology itself is an inter-disciplinary sciences and remote sensing technique provides spatio-temporal physical and environmental knowledge on regional & global scale, knowledge/appreciation about multi-disciplinary earth & environmental sciences subjects are most desirable.

- a keen & in-depth observation about ground realities (in remote sensing parlance, it is fashioned to name it as 'ground-truth') and relating these sample ground observations to image information of much larger geographic dimensions.

IV. PRESENT TRAINING & EDUCATION PROGRAMS

Although historically remote sensing technique, through use of aerial photography, are in use in topographic survey and civil engineering since 1950's, its most recent use in hydrology and water resources engineering has started with the advent of satellite remote sensing since 1970's. With the ready availability of satellite data from Landsat series of satellites, initial reaction was to cash on immediate information needs in hydrology (flood inundation area, snow cover, landuse-landcover in river basins etc.), since tools & techniques of basic air-photo interpretation are already available to hydrologists.

While professional organisation like United States Geological Survey took this lead, Civil Engg. Deptt. & Geography Depts. of many universities in USA started in-house case studies as well as offering remote sensing as a minor paper in graduate programs. From this small, hesitant but hectic beginning, training & education in remote sensing in hydrology is now quite widespread in many countries in the world including some significant roles taken by multi-national organisations like FAO, UNDP, ESCAP, UNESCO; international professional societies like IAHS; and international training institute like ITC (of Netherlands).

IV.1 Indian Scenario

There are many professional organisations and universities in India which impart training of short & long durations and conduct academic programs in remote sensing. But specific to hydrology, such programs are few and in many instances not well structured to cover entire gamut of 'satellite hydrology'. Reason for this may be:

- since water resources being entirely in governmental sector, and this sector is more or less organised with established schools of thought & practice in water resources assessment, development & management, there is inherent hesitation to embrace & assimilate new technology offered by remote sensing in hydrological science.

- remote sensing technique itself has not reached to a level to meet challenges in hydrological science, which require

(i) much more frequent observations (hourly/daily/weekly), (ii) sub-soil and under-water

information, (iii) characterisation of hydrologic processes, (iv) hydrologic modelling, (v) accuracy & reliability of prediction/ forecasting, (vi) hydrologic uncertainty, etc.

IV.1.1 Training

As is usually the practice everywhere, training is being mostly organised by the professional organisations, whereas, training as well as education program are conducted in universities in India.

In general it is realised that, there is a need to offer training at three different professional levels:

- Decision-makers, planners, managers and administrators.
- Middle-level supervisory officers, engineers or scientists.
- Working-level scientists and engineers.

The training course for decision makers, planners, managers and administrators is usually designed for 4 to 5 days duration, which is in the form of a discussion session with example of case studies indicating advantages, limitations and cost-benefit analysis of using remote sensing techniques.

The training course for middle level supervisory officers, engineers & scientists is designed for 2-weeks to 8-weeks duration covering basic principles & applications of remote sensing in hydrology, data processing techniques, practical aspects of problem solving in specific themes in hydrology. Here, for someone who is already trained, it provides updating of skill in a specialised theme, for example, watershed management, flood plain management etc.

The training course for working level scientists & engineers is designed for 10 months duration and is tailored mainly for in-service engineers and scientists. The course curriculum is quite comprehensive encompassing a wide spectrum of subjects in remote sensing technology, its application in hydrology, water resources and allied disciplines, emphasis on image interpretation & digital image processing, field observation, data integration with a dissertation project at the end. Training performance is evaluated through credit/grade system. This training course is a mix of academic curriculum and practical training & provides a solid foundation to take up remote sensing studies in hydrology.

In many of these organisations, short duration courses are variously termed as: Orientation Course, Familiarisation Course, Appraisal Course, On-the job Training Course.

Table 1 shows a list of such organisations/ universities where training in remote sensing in hydrology are being conducted, either on regular basis or occasionally. The list & associated information are, however, not exhaustive but indicative only.

IV.1.2 Education

Few universities and IITs have the academic programs at M.Tech. level offering specialisation in remote sensing (Table 2). These programs are mostly organised in the Civil Engineering Department where a strong fundamental on the subject of photogrammetry, surveying & geodesy, water resources engineering, environmental engineering exists. However, strong remote sensing content of hydrology or water resources engineering as an education program is at-present not available in any of the universities/IITs in India. Similarly, in Ph.D. programs, there are some contents of research in remote sensing in hydrology. In comparison to this situation, ITC of Netherlands offers training-cum-education program on "Water Resources Surveys" (with emphasis on 'Watershed Management & Conservation Planning') at Post graduate diploma (11 months), M.Sc. (additional 9 months) and Ph.D. (3 years) level. In recent times, to make available greater number of educated manpower in the country and to make popular remote sensing as a subject of study at graduate/post graduate level in more universities. IITs & engineering colleges in India, University Grant Commission (UGC) has drawn up curriculum on remote sensing as a component subject of hydrology & water resources engineering stream, amongst other disciplines course curriculum, of one full paper.

Table 1; Training Progress in "Remote Sensing in Hydrology in India"

	INSTITUTE/ORGANISATION/UNIVERSITY	LEVEL OF TRAINING	DURATION	HDYROLOGY/WATER RESOURCES SUBJECTS COVERED	FREQUENCY
1.	Indian Institute of Remote Sensing, Dehradun	Post Graduate Diploma	10 months	all subjects covered in hydrology & water resources	Regularly Once in a year
		Certificate Course	2 weeks	Hydrologic theme-specific (e.g. Watershed Management, Floodplain Management)	Regularly Once in a year
			4 days	Hydrology is discussed as part of multi-disciplinary program	Regularly Once in a year
2.	National Remote Sensing Agency, Hyderabad	Certificate Course	5 days	Hydrology is discussed as part of multi-disciplinary program	Regularly Once in a year
			8 Week	Water Resources	Occasionally
3.	Space Application Centre, Ahmedabad	On-the-job training Course	12 weeks	conducted as part of demand of on-going Application project.	Occasionally
4.	Centre of Studies in Resources Engg., IIT, Bombay	Certificate Course	32 weeks	Water Resources is covered as part of multi-disciplinary program	Once in a year
			1 week	Hydrology & Water Resources	Once in a year
5	Institute of Remote Sensing, Anna Univ. Madras	Certificate Course	short duration	Water Resources	Occasionally
6.	Others				
	National Institute of Hydrology, Roorkee	Certificate Course	short duration (variable from time to time)	themes covered in hydrology & Water Resources	Occassionally
	University of Roorkee				

* Information is not exhaustive, but indicative only.

Table 2: Education Progress in "Remote Sensing in Hydrology" in India

	UNIVERSITY	DEPARTMENT	LEVEL OF EDUCATION	DURATION	SUBJECT OF SPECIALISATION	HYDROLOGY/WATER RESOURCES SUBJECTS COVERED	FREQUENCY
1.	Indian Institute of Technology, Kanpur	Civil Engg.	M.Tech.	18 Months	Remote Sensing	*	Regularly
2.	Indian Institute of Technology, Bombay	Civil Engg.	M.Tech.	18 Months	Remote Sensing	*	Regularly
3.	University of Roorkee, Roorkee	Civil Engg.	M.Tech.	18 Months	Remote Sensing & photogrammetic Engg.	*	Regularly
4	Anna University, Madras	Institute of Remote Sensing	M.Tech.	18 Months	Remote Sensing	Remote Sensing in Hydrology & Water Resources as one of the subjects	Regularly
5.	Andhra University	Geo-Engg.	M.Tech.	18 Months	Remote Sensing	*	*
6.	Ajmer University Ajmer	B.M. Brila Science & Technology Centre, Jaipur	M.Tech.	18 Months	Remote Sensing	Remote Sensing in Hydrology & Water Resources as one of the subjects	*
7.	Jawaharlal Nehru Technological Univ. Hyderabad	Remote Sensing Centre	M.Tech.	18 Months	Remote Sensing	Remote Sensing in Hydrology & Water Resources as one of the subjects	Regularly

Note: - Information is not exhaustive, but indicative only.
- A number of Universities/IITs/Engg. Colleges offer 'remote sensing' as a major/minor subject in M.E./M.Tech. education curriculum. However, curriculum content of 'Remote Sensing in hydrology & water resources' is not known.

* : not known.

IV.1.3 Course Curriculum

Course Curriculum in remote sensing training & education in hydrology is constantly in evolving phase, as it happens in any new technology. In most cases for training of short duration, it is driven by the needs of the users. Typically, all training & education programs are structured into following three components:

- Remote sensing technology
- Remote sensing application in hydrology & water resources
- Case study demonstration/hands-on-experience/ dissertation project work.

While on education program at M.Tech. level on "Remote Sensing in Hydrology" has not come up in any of the universities in India (as can be seen in Table 2), rather 'Remote Sensing' is offered as a specialisation within the Civil Engineering domain, where hydrology & water resources are also lessoned as one of the subjects; in training program, the course curriculum is more or less transparent. General course content of Short Duration Course (2 to 8 weeks) and Post Graduate Diploma training course (10 months) are cited here as an example. All training programs are more weighted on practical work in laboratory & field including hands-on-experience in image processing & GIS system, supported with lecture presentation about principles, method/ tools, application/case studies.

Short Duration Course

This type of course is typically structured as outlined below:

- Physics of remote sensing, remote sensing data characteristics, image interpretation and digital image processing techniques, geo-informatics technology.
- Remote sensing application in particular theme(s) in hydrology & water resources
- Hands-on-experience on interacts image processing system and GIS modules.

Post Graduate Diploma Course

The course is designed to provide adequate knowledge and practice into the utility of remote sensing technique for hydrology and water resources studies. The main objectives of the course are:

- to train water resources engineers and scientists in theory and practice of remote sensing applications to water resources.
- to initiate water resource specialists to develop an aptitude for synchronising conventional and remote sensing methods of study.
- to acquaint them with the techniques of remote sensing data acquisition, data products, data processing and their utility.
- to give a good working knowledge of the use of remote sensing technique for water resources assessment, development and management.

The curriculum program is designed in modular structure for flexibility to the trainees as well as to give a distinctive character from fundamentals of technology to application to dissertation project modes.

Module 1 (spread-over 3 months) is introductory to the science & technology of photogrammetric engineering and remote sensing involving theoretical and practical studies of image interpretation and digital data analysis. The key subjects included in this module are:

- Photogrammetry
- Physics of Remote Sensing
- Remote Sensing for near-surface observation
- Air-photo & Satellite Image Interpretation Techniques
- Pattern Recognition & Digital Image Processing Technique
- Geographic Information system
- Mathematics, Statistics & Probability theory

- Principles of Cartography & Map Reproduction

Module 2 (spread-over 4 months) encompasses comprehensive studies of state-of-art knowledge and potential of remote sensing applications in various themes in hydrology and water resources engineering using visible, near-IR, thermal, microwave remote sensing data, image interpretation, digital image processing and GIS applications. The broad subjects included in this module are:

- Multi-disciplinary Water Science: Surface Water Hydrology, Ground Water Hydrology, Agro-hydrology, Forestry & Ecology, Applied Geomorphology

- Water Resources Assessment: Surface Water Inventory, Rain-fall-Runoff Modelling, Snow-melt Runoff Forecasting, Ground water Potential Zone Mapping

- Water Resources Development: Watershed Development, Irrigation Command Area Development, River Engineering, Geo-Technical Engineering, River Valley Investigation & Planning

- Water Resources Management: Flood, Drought, Water Quality, Reservoir Sedimentation, Water-logging & Drainage.

Module 3 (spread-over 3 months) incorporates field project work (case study) on candidate's choice of topics & interest (outlined in Module 2) and at geographic location of interest to a trainee's organisation. The case studies are designed for hands-on-experience in various remote sensing data collection and analysis techniques in a study project frame. The results are presented in the form of dissertation thesis/report.

V. CONCLUDING REMARKS

- The past two decades have witnessed a significant improvement in our knowledge and practice in satellite hydrology and in aero-space technology-based water resources engineering. With a host of remote sensing satellites/sensors under command to receive data over wide geographic environment and the data processing capabilities on the ground, prospect for embracing new technologies in the nineties is very high. Training & education have to keep pace with this new environment.

- However, ultimate bet is the User to accept any new technology. This is more appropriate to remote sensing, since the technology is truly "user-need driven". Towards this, a multi-prong approach should be aimed at by training & educational institutions : technology development/ R & D training and education, application projects, technology transfer, user interaction.

- Training and education also dispel disbelief and mis-conception about advantage and limitation in remote sensing technology & its application in water science. Because, without proper training and education, if an over- exaggerated claim is made of a new technique without necessary supporting evidence or rigorous tests for the real-world hydrologic problems, then user will lose confidence when he comes to apply the methods himself. This causes delay in the progress toward acceptance of important new tools, like remote sensing technique, in hydrology. The limits of accuracy and application of these tools must always be emphasized.

- This puts an important role on 'training & education' and an equally important responsibility on the "trainers and educationists".

VI REFERENCES

Beek, K.J. 1992. "Remote Sensing Education and Training for Sustainable Development: The Challenge Ahead for ITC and IIRS" Proc. of IIRS Silver Jubilee Seminar on : Training & Education in Remote Sensing for Resource Management, Dehradun P. 7-16.

Bruen, M. 1993. "Education Systems for Hydrology Technicians", Technical Document in Hydrology, UNESCO, Paris.

Chakraborti, A.K., 1992. "Training and Research in Water Resources : Experience at IIRS".

Proc. IIRS Silver Jubilee Seminar on "Training & Education in Remote Sensing for Resource Management" Dehradun. P. 101-107.

Chakraborti, A.K., 1993. "Advance in Remote Sensing Application in Hydrology". Key Note Pages presented in International Conference on Hydrology and Water Resources, New Delhi.

Chandra, S. 1989. "Application of New Trends in Water Resources Engineering" Proc. International Seminar on : Education and Training in Water Resources in Developing Countries. Aurangabad, India.

Fleming, G. 1975. "Computer Simulation Techniques in Hydrology". Elsuvier Publishing Co.

Indian Space Research Organisation, 1993. "Remote Sensing in India: Facilities & Infrastructure" Tech. Report. DOS-NNRMSS-TR-97-93, Bangalore.

Indian Space Research Organisation, 1990. "Remote Sensing Training & Education Opportunities in India". Brochure, NNRMS Br. 7, Bangalore.

Indian Institute of Remote Sensing, 1993. "Post Graduate Diploma Course on Remote Sensing Application to Water Resources", Information Brochure, Dehradun.

Sikka, A.K., Bhatt, P.N. 1987. "Training and Education in Watershed Management" Proc. National Symposium on Hydrology, Roorkee, P. VIII - 15 - 27.

Singh, V.P. 1989. "Role of Computers in Water Resources Education". Proc. International Seminar on :Education and Training in Water Resources in Developing Countries, Aurangabad, India.