COURSE SYLLABUS
for
Ph.D (Agril. Engg.)
in
Irrigation and Drainage Engineering

(Approved by Academic Council vide resolution No. 7644, dat. 07.12.2022)

ODISHA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
BHUBANESWAR-751003

Course Title with Credit Load

Ph.D. (Agril. Engg.) in Irrigation and Drainage Engineering

Major Courses (Requirement: 12 Credits)

Course Code	Course Title	Credit Hours
IDE 601*	Recent Developments in Irrigation Engineering	2+1
IDE 602*	Advances in Drainage Engineering	2+1
IDE 603	Hydro-Mechanics and Ground Water Modeling	3+0
IDE 604	Soil-Water-Plant-Atmospheric Modeling	2+1
IDE 605	Plant Growth Modeling and Simulation	2+0
IDE 606	Multi Criteria Decision Making System	2+0
IDE 607	Water Resources System Engineering	2+1

*Compulsory course

Minor Courses (Requirement: 06 Credits)

Course Code	Course Title	Credit Hours
SWCE 601	Advances in Hydrology	2+1
SWCE 602	Soil and Water Systems Simulation and Modeling	2+1
SWCE 603	Reservoir Operation and River Basin Modeling	2+1
SWCE 604	Modeling Soil Erosion Processes and Sedimentation	2+1
ASCE 501	Dimensional Analysis and Similitude	2+1
FMPE 502	Testing and Evaluation of Agricultural Equipment	2+1
FMPE 503	Ergonomics and Safety in Farm Operation	2+1
REE 602	Thermo-chemical conversion of Biomass	2+1
REE 609	Energy Planning Management and Economics	3+0
PFE 604	Agril. Waste and By-Product Utilization	2+1
CSE 503	Neuro-Fuzzy Application in Engineering	2+1
CSE 506	Digital Image Processing	2+1
ME 515	Computer Aided Design	2+1
Any other course(s) of other department can be taken as per recommendations of the student's advisory committee.		

Supporting Courses (Requirement: 05 Credits)

Course Code	Course Title	Credit Hours
CPE-RPE*	Research and Publication Ethics	1+1
ASCE 601	Environmental Engineering for Plants and Animals	3+0
STAT 601	Theory of Design and Analysis of Experiment	2+1
Courses from subject matter fields (other than major) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee		

*****Course has been made compulsory by UGC for PhD students. Course code and its detailed course outline to be adopted in toto as recommended by UGC.

Course Code	Course Title	Credit Hours
SWCE 691	Seminar-I	0+1
SWCE 692	Seminar-II	0+1
SWCE 699	Research for thesis	0+75

SEMESTER WISE COURSE DISTRIBUTION

Ph.D (Agril. Engg.) Irrigation & Drainage Engineering

Sl. No.	Course Title	Course No.	Major	Minor	Supporting
SEMESTER-I					
1	Environmental Engineering for Plants and Animals	ASCE 601			2+1
2	Recent Developments in Irrigation Engineering	IDE 601*	2+1		
3	Hydro-Mechanics and Ground Water Modelling	IDE 603	3+0		
4	Soil-Water-Plant-Atmospheric Modelling	IDE 604	3+0		
5	Water Resources Systems Engineering	IDE 607	2+1		
6	Reservoir Operation and River Basin Modelling	SWCE 603		2+1	
7	Modelling Soil Erosion Processes and Sedimentation	SWCE 604		2+1	
8	Thermo-chemical conversion of Biomass	REE 602		2+1	
9	Neuro-Fuzzy Application in Engineering	CSE 503		2+1	
10	*Library and Information Service*	*PGS 501*	*1+0 (NC)*		
11	*Basic Concepts in Laboratory Techniques*	*PGS 504*	*0+1 (NC)*		
SEMESTER-II					
1	Research and publication Ethics	CPE-RPE*			1+1
2	Theory of Design and Analysis of Experiment	STAT 601			2+1
3	Advances in Drainage Engineering	IDE 602*	2+1		
4	Plant Growth Modelling and Simulation	IDE 605	2+0		
5	Soil and Water Systems Simulation and Modelling	SWCE 602		2+1	
6	Waste Water Treatment and Utilisation	SWCE 605		3+0	
7	Hydro-Chemical Modelling	SWCE 606		2+0	
8	Energy Planning Management and Economics	REE 609		3+0	
9	Agril. Waste and By-Product Utilization	PFE 604		2+1	
10	Advances in Machinery for Precision Agriculture	FMPE 602		2+1	
11	Digital Image Processing	CSE 506		2+1	
12	Thesis Research	IDE 699 (0+5)			
13	*Technical Writing and Communication Skills*	*PGS 502*	*0+1 (NC)*		
14	*Agricultural Research, Research Ethics and Rural Development Programmes*	*PGS 505*	*1+0 (NC)*		
SEMESTER-III					
1	Multi Criteria Decision Making System	IDE 606	2+0		
2	Advances in Hydrology	SWCE 601		2+1	
3	Water Quality and Pollution Control	ASCE 502		2+1	
4	Soft Computing Techniques in Engineering	CSE 504		2+1	
5	Thesis Research	IDE 699 (0+15)			
6	*Intellectual Property and its Management in Agriculture*	*PGS 503*	*1+0 (NC)*		
SEMESTER-IV					
1	Thesis Research	IDE 699 (0+15)			
SEMESTER-V					
1	Thesis Research	IDE 699 (0+20)			
2	Seminar-I	IDE 691 (0+1)			
SEMESTER-VI					
1	Thesis Research	IDE 699 (0+20)			
2	Seminar-II	IDE 692 (0+1)			

* The courses are compulsory for Master's and Ph.D programme respectively.

NC: Non-credit (italic) courses are exempted if undergone during Master's programme.

Type of course	Minimum credit hours
A. Course Work	
i) Major course	12
ii) Minor course	06
iii) Supporting course	05
iv) Non–credit compulsory course	--

v) Seminar	02
Sub-Total	**25**
B. Thesis	75
Grand Total	**100**

Course Contents
Ph.D.(Agril. Engg.) in Irrigation and Drainage Engineering

I. **Course Title** : **Recent Developments in Irrigation Engineering**

II. **Course Code** : **IDE 601**

III. **Credit Hours** : **2+1**

IV. **Aim of the course**

To focus the students for the recent designs progressed in surface irrigation systems, surface and subsurface drip irrigation systems and for utilizing good and poor- quality waters for sustaining crop productivity.

V. **Theory Unit I**

Geospatial analysis of hydraulic properties of the soil. Surge flow irrigation systems. One dimensional and two-dimensional zero inertia modelling of border irrigation, surge irrigation and furrow irrigation. Integral equation solutions to surface irrigation. Design of irrigation runoff recovery systems. Cablegation: Automated supply for surface irrigation. Analyzing wind distortion in sprinkler irrigation systems uniformity.

Unit II

Design of sub-surface drip irrigation systems. Modeling soil water regimes and solute distribution emanating from surface and sub-surface drip irrigation systems. Recent developments in designs of surface and sub-surface drip irrigation systems. Effects of emitter variability and plant and soil variability on soil moisture distribution uniformity. Irrigation scheduling through partial root zone irrigation. Low energy drip irrigation systems.

Unit III

Drip irrigation for poor quality water. Drip automation for time and volume. Drip irrigation system modification for waste water utilization. Modeling deficit irrigation and crop yield in response to hydraulic variation of the system and distribution uniformity of the soil-crop water fertilizer response function. Crop water salinity response function.

Unit IV

Drip irrigation in command area development. Mulching and its effect on crop productivity. Analyzing moisture and temperature profiles with time and depth. Effect of shading and mulching on crop productivity, vapour phase movement.

VI. **Practical**

Designing border irrigation using zero inertia model, volume balance approaches, evaluating surge flow irrigation systems, operation of segmented border irrigation systems for enhancing water use efficiency, geospatial analysis of soil properties, design and planning of surface drip irrigation systems using various designs, design of subsurface drip irrigation, analyzing three dimensional moisture movement under subsurface drip irrigation using simple empirical models, design and planning of surface and subsurface drainage systems, developing the irrigation schedules using partial root zone irrigation, seasonal and dated production functions for forecasting crop yield

VII. **Learning outcome**

The students will be able to design, operate and maintain surface irrigation systems, surface and sub-surface pressurized irrigation systems and managing crop productivity with poor quality of waters without deteriorating soil conditions.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Geospatial analysis of hydraulic properties of soil: Geospatial analysis, Spatial interpolation, Data quality assessment, Vegetation analysis, Correlation analysis	3
2.	Surge flow: Effect of surging on infiltration and surface flow hydraulics, surge flow systems	2
3.	Zero inertia modeling of border irrigation	2
4.	Integral equation solutions to surface irrigation: Border and furrow irrigation method	2
5.	Design of irrigation runoff recovery systems: Border and furrow irrigation method	3
6.	Cablegation: Automated supply for surface irrigation	2
7.	Wind effects on sprinkler irrigation performance: Analyzing wind distortion in sprinkler irrigation system uniformity	2
8.	Design of sub-surface drip irrigation systems, Modeling soil water regimes and solute distribution emanating from sub-surface drip irrigation systems	3
9.	Effects of emitter variability and plant and soil variability on soil moisture distribution uniformity	2
10.	Irrigation scheduling through partial root zone irrigation.	2
11.	Low energy drip irrigation systems	2
12.	Drip irrigation for poor quality water, Drip automation for time and volume, Drip irrigation system modification for waste water utilization	2
13.	Modeling deficit irrigation and crop yield in response to hydraulic variation of the system and distribution uniformity of the soil-crop water fertilizer response function, Crop water salinity response function	3
14.	Drip irrigation in command area development	2
15.	Mulching and its effect on crop productivity, Analyzing moisture and temperature profiles with time and depth, Effect of shading and mulching on crop productivity, vapour phase movement	3
Total		**35**

IX. List of Practicals

S. No.	Topic	No. of Practical
1	Study of geospatial analysis of soil properties	2
2	Design of border irrigation using zero inertia model	1
3	Design of border irrigation using volume balance approach	1
4	Design of irrigation runoff recovery system for border irrigation method	1
5	Design of irrigation runoff recovery system for furrow irrigation method	1

6	Design and planning of cablegation system	1
7	Analysis of wind distortion in sprinkler irrigation system uniformity	1
8	Design and planning of subsurface drip irrigation system	1
9	Analysis of three dimensional moisture movement under subsurface drip irrigation using simple empirical models	1
10	Development of irrigation schedules using partial root zone irrigation	2
11	Modeling deficit irrigation and crop yield in response to hydraulic variation of the system and distribution uniformity of the soil-crop water fertilizer response function	1
12	Analysis of moisture and temperature profiles with time and depth	1
13	Development of seasonal and dated production functions for forecasting	1
Total		**15**

X. Suggested Reading

- Cuenca RH. 1989. *Irrigation System Design*: *An Engineering Approach*. Prentice Hall, NewYork.
- Hoffman GJ, Evans RG, Jensen ME, Martin DL and Elliot RL. (ed). 2007. *Design and Operation of Farm Irrigation Systems*. American Society of Agricultural Engineers St. JosephMichigan.
- James LG. 1988. *Principles of Farm Irrigation System Design*. John Wiley and Sons, New York, USA.
- Nakayama FS and Bucks DA. 1986. *Trickle Irrigation for Crop Production: Design, Operation and Management*. Elsevier Publications, Amsterdam.
- Skogerboe GV and Walkar WR. 2008. *Surface Irrigation Theory and Practice*. Prentice Hall, New York.

I. Course Title : Advances in Drainage Engineering

II. Course Code : IDE 602

III. Credit Hours : 2+1

IV. Aim of the course

To provide comprehensive knowledge of advances in land drainage, synthetic materials for drainage systems, linear flow laws and environmental issues related to drainage.

V. TheoryUnit I

Physics of land drainage. Forces, surface tension and energy effects water. Energy of soil water. Capillary potential.

Unit II

Devices to measure capillary potential. Hystersis, Darcy’s law. Synthetic materials for drainage systems. Environmental issues related to drainage. Socio-economic impacts of drainage systems.

Unit III

Laplace equation its derivation and solution in various forms. Boundary value problems, Liner flow laws. Drainage criteria saturated flow theory, steady flow and non steady flow. Controlled drainage for reducing agricultural non-point pollution. Application of simulation models for drainage systems.

Unit I V

Flow equations in general and the approach. Flow problem and physical boundary conditions.

VI. Practical

Steady state and non steady state flow problems. Measurement of capillary potential. Use of various synthetic materials under the field condition. Use of simulated models for drainage system.

VII. Learning outcome

The student will be familiar about energy of soil water, capillary potential, drainage material and various sources of agricultural pollution and also able to develop and apply simulation model for management of drainage system for particular area.

VIII. Lecture Schedule

S. No.	Topic	No. of Lectures
1	Physics of land drainage: Forces acting on movement of water through soil profile, surface tension, capillary forces and energy effects movement of water, Energy of soil water	5
2	Capillary potential: Effect of capillary potential on movement of water through porous media, devices to measure capillary potential.Hystersis effect in drainage of soil, Darcy's law	3
3	Synthetic materials for drainage systems: Design of filter and envelop for drainage system with synthetic materials	2
4	Environmental issues related to drainage. Socio-economic impacts of drainage systems	2
5	Drainage Flow Equation: Laplace equation its derivation and solution in various forms, Liner flow laws	4
6	Boundary value problems: Initial and boundary condition and its solution	3
7	Drainage criteria: Drainage criteria for different type of soils and crops, guidelines for design and installation of drainage system	2
8	Saturated flow theory: steady flow and non steady saturated flow	3
9	Controlled drainage for raising crop and reducing agricultural non-point pollution	2
10	Application of simulation models for drainage systems (DRAINMOD, SALTMOD, etc)	4
11	Flow equations: general drainage flow equations and the approach, drainage flow problems and solutions with physical boundary conditions	3
Total		33

IX. List of Practicals

S. No.	Topic	No. of Practicals
1	Steady state drainage flow problems	3
2	Unsteady state drainage flow problems	3
3	Measurement of capillary potential	2
4	Use of various synthetic materials for drainage filter under the field condition	2
5	Design of filter and envelop with synthetic materials	2
6	Use of simulated models for drainage system	4

Total	16

IX. Suggested Reading

- Chauhan HS. 1999. *Mathematical Modeling of Agricultural Drainage, Ground Water and Seepage*. ICAR Publication New Delhi.
- Kirkham DL and Powers WL. 1972. *Advanced Soil Physics*. Inter Science, New York.
- Lambert K Smedema, Willem FV, Lotman and David Rycroft. 2004. *Modern Land Drainage: Planning, Design and Management of Agricultural Drainage Systems.* CRC Press.
- Ritzema HP. (Ed.). 1994. *Drainage Principles and Applications*. ILRI.
- Skaggs RW and Schilfgaarde Jan Van. 1999. *Agriculture Drainage*. Monograph No. 17. American Society of Agronomy Madison, Wisconsin, USA.

I. Course Title : **Hydro-Mechanics and Groundwater Modeling**

II. Course Code : **IDE 603**

III. Credit Hours : **3+0**

IV. Aim of the course

To acquaint students about the concept of soil aquifer system, unsaturated flow models, numerical modeling of groundwater flow, theory of krigging and movement of groundwater in fractured and swelling porous media.

V. Theory Unit I

Concept of soil aquifer system, flow of water in partially saturated soils. Partial differential equation of flow, pressure under curved water films, moisture characteristic functions.

Unit II

Physical models, Analog models, Mathematical modelling, Unsaturated flow models, Numerical modelling of groundwater flow, Finite difference equations and solutions. Successive over relaXation. Alternating direction implicit procedure. Crank Nicolson equation. Iterative methods. Direct methods. Inverse problem. Finite element method.

Unit III

Determination of unsaturated hydraulic conductivity and model for its estimation. Diffusivity and its measurement. Infiltration and eXfiltration from soils in absence and presence of water table.

Unit IV

Fence diagram and aquifer mapping. Movement of groundwater in fractured and swelling porous media. Spatial variability, theory of krigging.

Unit V

Data requirements. Conceptual model design: Conceptualization of aquifer system. Parameters, Input-output stresses, Initial and Boundary conditions. Model design and eXecution: Grid design, Setting boundaries, Time discretization and transient simulation. Model calibration: Steady state and unsteady state. Sensitivity analysis. Model validation and prediction. Uncertainty in the model prediction.

VI. Learning outcome

The students will be able to understand compleX mechanics movement of water in soil systems and also able to estimate the statistical parameters for better understanding of soil aquifer system, model validation and prediction.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Concept of soil aquifer system	1
2.	Flow of water in partially saturated soils	1
3.	Partial differential equation of flow	1
4.	pressure under curved water films, moisture characteristic functions	1
5.	Different types of Models used in hydrology and Groundwater	1
6.	Unsaturated flow models	1
7.	Numerical modelling of groundwater flow	1
8.	Finite difference equations and solutions, Finite difference equations and solutions, Alternating direction implicit procedure	4
9.	Crank Nicolson equation. Iterative methods	2
10.	Inverse problem. Finite element method	1
11.	Determination of unsaturated hydraulic conductivity and model for its estimation	2
12.	Diffusivity and its measurement	1
13.	Infiltration and eXfiltration from soils in absence and presence of water table	2
14.	Fence diagram and aquifer mapping	2
15.	Movement of groundwater in fractured and swelling porous media, Spatial variability, theory of krigging	4
16.	Data requirements. Conceptual model design: Conceptualization of aquifer system. Parameters, Input-output stresses, Initial and Boundary conditions	4
17.	Model design and eXecution: Grid design, Setting boundaries, Time discretization and transient simulation	4
18.	Model calibration: Steady state and unsteady state. Sensitivity analysis. Model validation and prediction. Uncertainty in the model prediction	6
19.	Course Seminar	4
Total		**43**

VIII. Suggested Reading

- Anderson MP and Woessner WW. 1992. *Applied Groundwater Modelling: Simulation of Flow and Advective Transport*. Academic Press, Inc.
- Elango L and Jayakumar R. 2001. *Modelling in Hydrology*. Allied Publishers Ltd.
- Fetter CW. 1999. *Contaminant Hydrogeology*. Prentice Hall.
- Kirkham and Powers. 1972. *Advanced Soil Physics*. John Wiley & Sons.
- Muskat M. 1937. *The Flow of Homogeneous Fluid through Porous Media*. McGraw Hill.
- Rushton KR. 2003.*Groundwater Hydrology: Conceptual and Computational Models. Wiley,*

I. **Course Title** : **Soil-Water-Plant-Atmospheric Modeling**

II. **Course Code** : **IDE 604**

III. **Credit Hours** : **2+1**

IV. **Aim of the course**

To impart the knowledge of measurement of radiation within plant cover, thermodynamics of flow through plant cells, heat transfer and radiation exchange under plant cover.

V. **Theory Unit I**

Radiation balance of earth's surface. Turbulent transport of heat and momentum. Radiation eXchange and heat transfer in a low plant cover.

Unit II

Measurement of radiation, leaf and air temperature, humidity and wind profiles within plant cover. Predicting potential evapotranspiration.

Unit III

Thermodynamics of flow through plant cells. Dynamics of water movement through soil plant atmosphere system. Stomatal aperture, photosynthesis and actual evapotranspiration relationship.

Unit IV

Production functions of evapotranspiration. Evapotranspiration in mathematical modelling and optimization of design and regulation of irrigation systems and for utilization of limited water resources in agriculture.

Unit V

Crop water requirement under protected cultivation and remote sensing-based modeling.

VI. **Practical**

Estimation of potential evapotranspiration. Measurement of ET parameters under open and protected cultivation and development of stochastic and deterministic models of ET. Use of software for estimation of crop water requirement and ET.

VII. **Learning outcome**

The students will be able to understand the measurement of radiation, photosynthesis and actual evapotranspiration relationship along with modeling of evapotranspiration.

VIII. Lecture Schedule

S. No.	Topic	No. of Lectures
1	Radiation balance of earth's surface	1
2	Turbulent transport of heat and momentum	2
3	Radiation exchange and heat transfer in a low plant cover	2
4	Measurement of radiation, leaf and air temperature, humidity and wind profiles within plant cover	2
5	Predicting potential evapotranspiration	2
6	Thermodynamics of flow through plant cells	2
7	Dynamics of water movement through soil plant atmosphere system	2
8	Stomatal aperture, photosynthesis and actual evapotranspiration relationship	1
9	Production functions of evapotranspiration	3

10	Evapotranspiration in mathematical modelling and optimization of design and regulation of irrigation systems and for utilization of limited water resources in agriculture	4
11	Crop water requirement under protected cultivation and remote sensing based modelling	4
Total		25

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Estimation of potential evapotranspiration using FAO 56 Penman Monteith equation	1
2.	Estimation of potential evapotranspiration using FAO Cropwat model	1
3.	Estimation of potential evapotranspiration using FAO ETo calculator	2
4.	Measurement of ET parameters under open condition	1
5.	Measurement of ET parameters under protected cultivation	1
6.	Development of stochastic models of ET	3
7.	Development of deterministic models of ET	3
8.	Use of software for estimation of crop water requirement and ET	2
Total		**14**

X. Suggested Reading

- Amarjit Basra. 1994. *Mechanisms of Plant Growth and Improved Productivity*. CRC Press New York.
- Daniel Hillel. *Advances in Irrigation*. All Volumes.
- Nieder AR and Benbi D. 2003. *Handbook of Processes and Modeling in the Soil-Plant System*. CRC Press New York.
- Peter J Gregory. *Plant Roots, their Growth Activity and Interaction with Soils.* Wiley Blackwell New York.

I. Course Title : Plant Growth Modeling and Simulation

II. Course Code : IDE 605

III. Credit Hours : 2+0

IV. Aim of the course

To impart the in-depth knowledge of plant growth modeling, type of modeling approach, quantitative analysis of photosynthesis and remote sensing-based modeling.

V. Theory Unit I

Introduction to plant growth modeling. Simulation and simulation language. Types of models and modeling approaches.

Unit II

Relational diagram of principle process. Structure of a generalized agricultural simulator. Input environment and techniques for monitoring plant environment. Process and aspects of growth and development. Input yield models. Quantitative analysis of photosynthesis, respiration, growth, water and nutrient uptake. Yield functions.

Unit IV

Remote sensing-based modeling and field variability of growth influencing factors.

VI. Learning outcome

The students will be able to know various plant growth models and their application based on input environmental parameters. Student will be acquainted with generalized agricultural simulator.

VIII. Lecture Schedule

S. No.	Topic	No. of Lectures
1	Introduction to plant growth modelling	4
2	Simulation and simulation language	4
3	Types of models and modeling approaches	4
4	Relational diagram of principle process	2
5	Structure of a generalized agricultural simulator	2
6	Input environment and techniques for monitoring plant environment	4
7	Process and aspects of growth and development. Input yield models	4
8	Quantitative analysis of photosynthesis, respiration, growth, water and nutrient uptake. Yield functions	3
9	Remote sensing-based modelling	3
10	Field variability of growth influencing factors	2
Total		**32**

IX. Suggested Reading

- Charls-Edwards DA. 1981. *The Mathematics of Photosynthesis and Productivity*. Academic Press, London.
- Evans LT. 1963. *Environmental Control of Plant Growth*. Academic Press, New York, USA.
- Goudriaan J and Van Laar HH. 1994. *Modelling Potential Crop Growth Process*. Kluweer Academic Publisher, Dordrecht, The Netherlands.
- Jones JW and Ritchie JT. 1990. *Crop Growth Models*. In: ASAE Monograph on Management of Farm Irrigation.
- Thorwey JHM and Johnson IR. 1990. *Plant and Crop Modelling: A Mathematical Approach to Plant and Crop Physiology*. Clarendon Press, OXford.

I. Course Title : **Multi Criteria Decision Making Systems**

II. Course Code : **IDE 606**

III. Credit Hours : **2+0**

IV. Aim of the course

To acquaint students about multi criteria decision making system which include multi-attribute decision making and multi-objective decision making.

V. Theory

Unit I

Introduction: MCDM overview, basic foundations and Pareto optimality elementary decision analysis. Decision trees and influence diagrams. Multi–attribute decision making (MADM): Deterministic utility theory, value decomposition, additive value decomposition, Multi–facility location analysis, expected utility theory, single attribute utility functions, multi –attribute overview, two–attribute utility models, multi–attribute computer programs, multi–attribute assessment.

Unit III

Multi-objective decision making (MODM): Vector optimization theory, weighting methods, weighting example. Linear vector optimization (LVOP), parametric decomposition, LVOP algorithm, LVOP example.

Unit IV

Non interactive and interactive methods: Geoffrion’s Bi-criterion method, linear goal programming, nonlinear and integer goal programming.

Unit V
Interactive trade-off methods: Zionts–Wallenius, Surrogate worth, Group decision making methods.

VI. Learning outcome

The students will be able to understand and learn to apply various techniques forthe best solutions of real-life command area and other hydrological problems.

VII. Lecture Schedule

S. No.	Topic	No. of Lectures
1	MCDM overview	1
2	Basic foundations and Pareto optimality elementary decision analysis	2
3	Decision trees and influence diagrams	1
4	Multi-attribute decision making (MADM): Deterministic utility theory, value decomposition, additive value decomposition	2
5	Multi-facility location analysis	1
6	EXpected utility theory	1
7	Single attribute utility functions	1
8	Multi-attribute overview	1
9	Two-attribute utility models	1
10	Multi-attribute computer programs and multi–attribute assessment	2
11	Multi-objective decision making (MODM)	1
12	Vector optimization theory	1
13	Weighting methods and examples related with weighting	2
14	Linear vector optimization (LVOP)	1
15	Parametric decomposition	2
16	LVOP algorithm and LVOP example	2
17	Non interactive and interactive methods	2
18	Geoffrion’s Bi-criterion method	1
19	linear goal programming, nonlinear and integer goal programming	2
20	Interactive trade-off methods	1
21	Zionts-Wallenius and Surrogate worth	2
22	Group decision making methods	2
Total		**32**

VIII. Suggested Reading

- Cohon JL. 2004. *Multiobjective Programming and Planning*. Dover Publications.
- Doumpos M and Grigoroudis E. 2013. *Multicriteria Decision Aid and Artificial Intelligence: Links, Theory and Applications.* Wiley-Blackwell.
- Figueira J, Greco S and Ehrgott M 2007. *Multiple Criteria Decision Analysis: State of the Art Surveys*. Springer.
- Tzeng GH and Huang JJ. 2011. *Multiple Attribute Decision Making: Methods and Applications*. Chapman and Hall/CRC.
- Tzeng GH and Huang JJ. 2013. *Fuzzy Multiple Objective Decision Making*. Chapman and Hall/CRC.

I. **Course Title : Water Resources Systems Engineering**

II. **Course Code : IDE 607**

III. **Credit Hours : 2+1**

IV. **Aim of the course**

To acquaint students about the concept of optimization and its application in water resources management, mathematical programming techniques and multi objective water resources planning.

V. **Theory**

Unit I

Concepts and significance of optimization in water resources management. Model development in water management. Objective functions, deterministic and stochastic inputs.

Unit II

Soil plant atmosphere system. Problem formulation. Mathematical programming techniques: Linear programming, simplex method.

Unit III

Non-linear programming, quadratic programming, integer programming. Transportation problem and solution procedure. Geometric programming and dynamic programming.

Unit IV

Application of optimization techniques for water resources planning. Conjunctive use of water resources. Crop production functions and irrigation optimization.

Unit V

Multi objective water resources planning. Critical path method. Programme evaluation and review technique. Economic models. Project evaluation and discounting methods.

VI. **Practical**

Assessment of water resources. Problems related to water allocation in agriculture under single and multiple cropping system. Use of computer software for linear and dynamic programming. Introduction to the use of other programming methods. Sensitivity analysis of different alternatives of water resources development and allocation. Analysis of water demand and supply. Analysis of Competitive demands for water by various sectors of development. Benefits and cost of water resources development.

VII. **Learning outcome**

The students will be able to identify objective function and components in water resource planning problems and also able to formulate and solve various mathematical programming models of water resource system as well as to develop conjunctive use and crop production function optimization models.

VIII. **Lecture Schedule**

S. No.	**Topic**	**No. of Lectures**
1	Concepts and significance of optimization in water resources management	1
2	Model development in water management	1
3	Objective functions, deterministic and stochastic input	1
4	Soil plant atmosphere system. Problem formulation. Mathematical programming techniques	1
5	Linear programming, simplex method	5
6	Non-linear programming, quadratic programming, integer programming	5
7	Transportation problem and solution procedure	3

8	Geometric programming	3
9	Dynamic programming	4
10	Application of optimization techniques for water resources planning	2
11	Conjunctive use of water resources	1
12	Crop production functions and irrigation optimization	2
13	Multi objective water resources planning. Critical path method	2
14	Programme evaluation and review technique	1
15	Economic models	2
16	Project evaluation and discounting methods	1
Total		**35**

IX. **List of Practicals**

S. No.	Topic	No. of Practicals
1	Assessment of water resources of the region	1
2	Problems on water allocation in agriculture under single and multiple cropping system	2
3	Familiarization with computer software for linear programming	3
4	Hands on exercise for non-linear programming on computer	3
5	Hands on exercise for dynamic programming on computer	3
6	Sensitivity analysis of different alternatives of water resources development and allocation	2
7	Analysis of water demand and supply	2
8	Benefits and cost of water resources development	1
Total		**17**

X. **Suggested Reading**

a. Larry WM. 1996. *Water Resources Handbook.* Mc-Graw-Hill.
b. Loucks DP *et al*. 1981. *Water Resources System Planning and Analysis.* Prentice Hall.
c. Rao SS. 1978. *Optimization Theory and Application*. Wiley Eastern.
d. Wallander WW and Bos M. 1990. *Water Resource System Planning and Management*.