SWS 6722
AI Modeling in Soil and Ecosystem Sciences

(AI: Artificial Intelligence)

Distance Education Course

INSTRUCTOR:
Dr. Sabine Grunwald, Professor, Soil, Water and Ecosystem Sciences Department, University of Florida, 2181 McCarty Hall, PO Box 110290, Gainesville, FL 32611.
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TIMES: Spring semester odd years

CREDIT HOURS: 3

ENROLLMENT CAP: 20

FORMAT: Lectures, readings, instructor facilitates class discussions, discovery and exploratory learning, and immersion in soil and ecosystem projects.

TIME: Wednesdays 6:15 – 8:10 pm U.S. Eastern time (11 Period and E1 Period); Zoom chat.

PREREQUISITES:
A statistics or quantitative methods graduate course (e.g., STA 6166, GEO 6160), working knowledge in GIS (e.g., SWS 5721C), and basic coding skills (Python and/or R). If you do not fulfill these requirements seek permission from the instructor to enroll in this course.

COURSE DESCRIPTION:
AI modeling to understand the properties and functions of soils and ecosystems.

COURSE GOALS AND OBJECTIVES:
The goals of this class are to critically think about AI modeling approaches in soil and ecosystem sciences and evaluate and create AI models.

Objectives:

1. Discover AI modeling approaches applied to soils and ecosystems.
2. Discuss data and AI algorithms applied to soils and ecosystems.
3. Create your own AI model on a topic related to soils and/or ecosystem science.

After completing this course, students will be able to critically think about AI modeling approaches in soil and ecosystem sciences and evaluate and create AI models.

What is AI Modeling:
Data-driven AI modeling aims to predict, assess or optimize soil health, crop health, soil and ecosystem indicators, functions, processes, responses, interactions, and change in soil-ecosystems. The purpose of integrative soil-ecosystem modeling is rooted in finding better answers to the wicked environmental challenges of our time including adaptation and mitigation to global climate change, carbon and climate-smart agricultural management, multi-hazard eco-disasters (e.g., floods, droughts, erratic climate), food security, soil and public health, development of sustainable, resilient and regenerative agricultural systems, and many more. AI models are built from soil, spectral, and environmental geospatial data to model complex soil-water-crop-management-climate-human relationships. Data-driven GeoAI has profound capacity to reshape our thinking of soil-ecosystems and how to sustain and regenerate them.

LEARNING APPROACH:
A discovery style of leaning is used in this course to facilitate learning. This means to open your eyes and learn through deep understanding of the AI paradigm. We learn through dialogue, playful exploration, critical reflection and discussion. Students will immerse themselves in the course topics through reading, discussion of case studies (e.g., hot topics in soil and ecosystem sciences, AI model applications in soil and ecosystem sciences), and design and conduct their own AI soil-ecosystem modeling projects. The instructor uses coaching techniques to facilitate the learning process, including targeted Q&A sessions, unlocking self-motivation to study, learning as exploration, and class discussions that acknowledge multiple perspectives.

COURSE ACTIVITIES:
Each student will work on the following:

1) Case study discussion: You will explore and discuss various published AI soil-ecosystem modeling studies.

2) AI modeling project: You will (i) Select a hot topic in soil and ecosystem sciences and discuss its significance; (ii) Conduct a brief literature review on this topic: focus on AI modeling approaches that have been used to study the selected topic (read and cite a minimum of 10 peer-reviewed journal articles, books, and/or book chapters); (iii) Identify research objectives to investigate the selected soil-ecosystem topic; (iv) Acquire soil and environmental data to meet the project objectives; (v) Apply at least two AI methods to the data; describe the methods to train and validate the model; assess model performance, conduct error and uncertainty analyses; (vi) Document and discuss results, (vii) Present the AI modeling results in class and submit a project report.

   The project encourages students to think critically and learn how to approach an unknown complex soil-ecosystem topic. Students have to demonstrate mastery, comprehension, application, and synthesis of a given set of data and concepts into a model framework.

COURSE WEB SITE:
UF Canvas course management system (eLearning): https://elearning.ufl.edu/

SOFTWARE AND CODING:
ArcGIS Pro, Python, and R.

READING MATERIAL:
Reading material in this course is based on journal articles available through the UF library or open science publications.

Reading examples:

Diaz-Gonzalez, F. A., Vuelvas, J., Correa, C. A., Vallejo, V. E., & Patino, D. (2022). Machine learning and remote sensing techniques applied to estimate soil indicators – Review. *Ecological Indicators*, *135*, 108517. https://doi.org/10.1016/j.ecolind.2021.108517

Grunwald, S. (2021). Grand challenges in pedometrics-AI research. *Frontiers in Soil Science - Pedometrics*, *1*(Article 714323), 1–8. https://doi.org/10.3389/fsoil.2021.714323

Grunwald, S. (2022). Artificial intelligence and soil carbon modeling demystified: Power, potentials, and perils. *Carbon Footprints*, *1*(5), 1–23. https://doi.org/10.20517/cf.2022.03

Khaledian, Y., & Miller, B. A. (2020). Selecting appropriate machine learning methods for digital soil mapping. *Applied Mathematical Modelling*, *81*, 401–418. https://doi.org/10.1016/j.apm.2019.12.016

LeCun, Y., Bengio, Y., & Hinton, G. (2015). Deep learning. *Nature*, *521*(7553), 436–444. https://doi.org/10.1038/nature14539

Liao, S. M. (Ed.). (2020). *Ethics of artificial intelligence*. Oxford University Press.

McBratney, A. B., Minasny, B., & Stockmann, U. (Eds.). (2018). *Pedometrics* (1st ed.). Springer.

Ng, W., Minasny, B., Montazerolghaem, M., Padarian, J., Ferguson, R., Bailey, S., & McBratney, A. B. (2019). Convolutional neural network for simultaneous prediction of several soil properties using visible/near-infrared, mid-infrared, and their combined spectra. *Geoderma*, *352*, 251–267. https://doi.org/10.1016/j.geoderma.2019.06.016

Padarian, J., Minasny, B., & McBratney, A. B. (2019). Using deep learning for digital soil mapping. *SOIL*, *5*(1), 79–89. https://doi.org/10.5194/soil-5-79-2019

Russell, S., & Norvig, P. (2020). *Artificial intelligence: A modern approach*. Pearson.

Wadoux, A. M. J.-C., Samuel-Rosa, A., Poggio, L., & Mulder, V. L. (2020). A note on knowledge discovery and machine learning in digital soil mapping. *European Journal of Soil Science*, *71*(2), 133–136. https://doi.org/10.1111/ejss.12909

Zhao, B., Zhang, S., Xu, C., & Liu, X. (2020). Spoofing in geography: Can we trust artificial intelligence to manage geospatial data? In X. Ye & H. Lin (Eds.), *Spatial synthesis. Human dynamics in smart cities.* (pp. 325–338). Springer. https://doi.org/10.1007/978-3-030-52734-1_19

Zhao, T., Wang, S., Ouyang, C., Chen, M., Liu, C., Zhang, J., Yu, L., Wang, F., Xie, Y., Li, J., Wang, F., Grunwald, S., Wong, B. M., Zhang, F., Qian, Z., Xu, Y., Yu, C., Han, W., Sun, T., … Wang, L. (2024). Artificial intelligence for geoscience: Progress, challenges, and perspectives. *The Innovation*, *5*(5), 1–25. https://doi.org/10.1016/j.xinn.2024.100691

RECOMMENDED TEXTBOOKS:

Select one of the books as supporting material to deepen your skills in the topical area of your AI modeling project: AI & agriculture **(AI-Ag),** AI general **(AI-G)**, AI & environmental sensing **(AI-E)**, AI & soils **(AI-S)**, AI technical and coding skills of machine learning models **(AI-T)**.

AI-T: Géron A. (2023). Hands-On Machine Learning with Scikit-Learn, Keras & TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems. O'Reilly Media.

AI-Ag: Kose U., Prasath V.B.S., Mondal M.R.H., Podder P., & Bharati S. (Eds.) (1st Ed.) (2022). Artificial Intelligence and Smart Agriculture Technology. CRC Press.

AI-S: Malone B.P., Minasny B, & McBratney A.B. (2017). Using R for Digital Soil Mapping. Springer.

AI-S: McBratney A.B., Minasny B., & Stockman U. (Eds.) (2018). Pedometrics (1st Ed.). Springer.

AI-E: Mohsen A., Razmjou A., & Beheshti A. (Eds.) (2022). Artificial Intelligence and Data Science in Environmental Sensing (1st Ed.). Academic Press.

AI-G: Russell S. & Norvig P. (2021). Artificial Intelligence – A Modern Approach (4th Ed.). Pearson.

GRADING:

Case study discussion (four graded discussions) – AI modeling in soil and ecosystem sciences: 40%

AI modeling project:

- First part (15%): Design of project (selection of topic and description of significance, literature review, and proposal how to conduct the project: data and methods).
- Second part (15%): Conduct the project and present model results.
- Third part (15%): Submit AI modeling project report.

Class presentations & participation: 15%

GRADING SCHEME:

Passing Letter Grade	Course Points	Grade Points
A	95-100	4.00
A-	90-94	3.67
B+	85-89	3.33
B	80-84	3.00
B-	75-79	2.67
C+	70-74	2.33
C	65-69	2.00
C-	60-64	1.67
D+	55-59	1.33
D	50-54	1.00
D-	45-49	0.67
E	45-below	0

Failing Grades	Course Points	Grade Points
E	0	0
WF	0	0
I	0	0
NG	0	0

Definitions
E = Failure
H = Deferred grade assigned only in approved sequential courses or flexible learning
I* / I = Incomplete
N* / NG = No grade reported
S = Satisfactory
U = Unsatisfactory
W = Withdrew
WF = Withdrew failing

The grading policy of UF will be followed in this course as outlined at:
https://catalog.ufl.edu/ugrad/current/regulations/info/grades.aspx#repeat

EXPECTATIONS AND GRADING POLICY IN THIS COURSE:
The AI modeling case studies will serve as examples to learn how AI is applied in soil and ecosystem sciences. The discussion of these case studies will stimulate critical thinking how to apply AI soil-ecosystem modeling. Different AI methods will be explored, and their pros and cons discussed. We will use the UF NaviGator AI that provides access to various Large Language Models (LLMs) in combination with peer-reviewed literature to explore various perspectives.

Students are expected to work independently on their AI modeling projects. Properly cite and give credit to data and literature sources used in your projects. In this course the antiplagiarism software Turnitin is used. Late submissions of the project reports will result in 15% reduction of points within 12 hours late submission and 30% reduction of points between 24 hours late submission. After more than 24 hours

late submission zero points will be assigned. All project reports need to be submitted through the UF course website. Submissions via email attachments will not be accepted.

The IT staff of the University of Florida provides the service to assist with technical problems (e.g., ArcGIS Pro software via UF Apps or UF's Software Licensing at the GeoPlan Center). R and Python are free to use.

A detailed weekly schedule and submission deadlines of course assignments will be provided on the course website in UF's eLearning (Canvas).

COURSE MODULES:

1. **Introduction to Soil and Ecosystem Modeling**
    a. Wicked soil and environmental problems
    b. Soil-landscape dimensions and conceptual models of soil-ecosystems
    c. Significance of spatial and temporal scales in ecosystem modeling
    d. Soil and environmental geodata and platforms to support AI modeling

2. **Digital Twins in Pedometrics and Environmetrics**
    a. Digital soil twins: Digital soil mapping and modeling approaches
    b. Digital twins of the total environment

3. **GeoAI Model Applications in Soil and Ecosystem Sciences**
    a. Soil carbon modeling, soil respiration and greenhouse gas emissions
    b. Soil health indicators
    c. Soil-ecosystem indices
    d. Smart agricultural systems
    e. Ecosystem functions and processes

4. **Overview AI Modeling in Soil and Ecosystem Sciences**
    a. The power, myths, risks, and perils of GeoAI?
    b. The foundation and history of AI in context of soil and ecosystem sciences
    c. Data-driven AI modeling vs. knowledge-based modeling
    d. AI vs. other modeling paradigms (statistical, geostatistical, fuzzy logic, probabilistic, Bayesian, state-budget, optimization, multi-agent, phenomenological, mechanistic process-based modeling)
    e. The human dimension in AI soil-ecosystem modeling
    f. Ethics of data-driven AI in soil science, ecosystem sciences, and agriculture and life sciences

5. **Specific AI Methods and Model Assessments**
    a. Types of AI approaches: Machine learning, deep learning, and reinforcement learning
    b. Empirical soil and environmental data and pseudo variables
    c. Feature selection methods
    d. AI model assessments (training/calibration, verification/validation, error metrics, and uncertainty assessment)
    e. Commonly used AI algorithms in soil and ecosystem sciences:
        - Classification and Regression Trees
        - Bagged Regression Trees
        - Boosted Regression Trees
        - Random Forest

- Quantile Regression Forests
- Support Vector Machines
- Support Vector Regression
- Partial Least Square Regression
- Cubist
- Artificial Neural Networks, ANN (backpropagation ANN, recurrent neural networks, RNN; convolutional neural networks, CNN)
- Long Short-Term Memory (LSTM)

f. Integration modeling (triangulation, hybrid modeling, coupled models, ensemble modeling, sequential modeling, meta-modeling)

ATTENDANCE AND MAKE-UP WORK

Absences

Students are responsible for satisfying all academic objectives as defined by the instructor. Absences count from the first class meeting.

In general, acceptable reasons for absence from or failure to participate in class include illness, serious family emergencies, special curricular requirements (e.g., judging trips, field trips, professional conferences), military obligation, severe weather conditions, religious holidays and participation in official university activities such as music performances, athletic competition or debate. Absences from class for court-imposed legal obligations (e.g., jury duty or subpoena) must be excused. Other reasons also may be approved.

You cannot participate in classes unless you are registered officially or approved to audit with evidence of having paid audit fees. The Office of the University Registrar provides official class rolls to instructors.

If you do not participate in at least one of the first two class meetings of a course or laboratory in which you are registered, and you have not contacted the department to indicate your intent, you can be dropped from the course. You must not assume that you will be dropped, however. The department will notify you if you have been dropped from a course or laboratory. You can request reinstatement on a space-available basis if you present documented evidence.

The university recognizes the right of the individual professor to make attendance mandatory. After due warning, professors can prohibit further attendance and subsequently assign a failing grade for excessive absences.

Religious Holidays

The Florida Board of Education and state law govern university policy regarding observance of religious holidays. The following guidelines apply:

- Students, upon prior notification to their instructors, shall be excused from class or other scheduled academic activity to observe a religious holy day of their faith.
- Students shall be permitted a reasonable amount of time to make up the material or activities covered in their absence.
- Students shall not be penalized due to absence from class or other scheduled academic activity because of religious observances.

If a faculty member is informed of or is aware that a significant number of students are likely to be absent from class because of a religious observance, the faculty member should not schedule a major exam or other academic event at that time.

A student who is to be excused from class for a religious observance is not required to provide a second party certification of the reason for the absence. Furthermore, a student who believes that he or she has been unreasonably denied an education benefit due to religious beliefs or practices may seek redress through the student grievance procedure.

Illness Policy

If you are absent from classes or examinations because of illness you should contact your instructors. You should contact your college by the deadline to drop a course for medical reasons. You can petition the Dean of Students Office to drop a course for medical reasons. The university's policy regarding medical excuse from classes is maintained by the Student Health Care Center.

Twelve-Day Rule

Students who participate in athletic or extracurricular activities are permitted to be absent 12 scholastic days per semester without penalty. (A scholastic day is any day on which regular class work is scheduled.) Instructors must be flexible when scheduling exams or other class assignments.

The 12-day rule applies to individual students participating on athletic or scholastic teams. Consequently, a group's schedule that requires absence of more than 12 days should be adjusted so that no student is absent from campus more than 12 scholastic days.

If you previously have been warned about absences or unsatisfactory work you should not incur additional absences, even if you have not been absent 12 scholastic days. It is your responsibility to maintain satisfactory academic performance and attendance.

ONLINE COURSE EVALUATION PROCESS

Student assessment of instruction is an important part of efforts to improve teaching and learning. At the end of the semester, students are expected to provide feedback on the quality of instruction in this course using a standard set of university and college criteria. These evaluations are conducted online at https://evaluations.ufl.edu. Evaluations are typically open for students to complete during the last two or three weeks of the semester; students will be notified of the specific times when they are open. Summary results of these assessments are available to students at https://evaluations.ufl.edu/results.

Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online via GatorEvals. Guidance on how to give feedback in a professional and respectful manner is available at https://gatorevals.aa.ufl.edu/students/. Students will be notified when the evaluation period opens, and can complete evaluations through the email they receive from GatorEvals, in their Canvas course menu under GatorEvals, or via https://ufl.bluera.com/ufl/. Summaries of course evaluation results are available to students at https://gatorevals.aa.ufl.edu/public-results/."

ACADEMIC HONESTY

As a student at the University of Florida, you have committed yourself to uphold the Honor Code, which includes the following pledge: "*We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honesty and integrity.*" You are expected to exhibit behavior consistent with this commitment to the UF academic community, and on all work submitted

for credit at the University of Florida, the following pledge is either required or implied: *"On my honor, I have neither given nor received unauthorized aid in doing this assignment*."

It is assumed that you will complete all work independently in each course unless the instructor provides explicit permission for you to collaborate on course tasks (e.g. assignments, papers, quizzes, exams). Furthermore, as part of your obligation to uphold the Honor Code, you should report any condition that facilitates academic misconduct to appropriate personnel. It is your individual responsibility to know and comply with all university policies and procedures regarding academic integrity and the Student Honor Code. Violations of the Honor Code at the University of Florida will not be tolerated. Violations will be reported to the Dean of Students Office for consideration of disciplinary action. For more information regarding the Student Honor Code, please see: http://www.dso.ufl.edu/sccr/process/student-conduct-honor-code. The updated (2018) UF Student Honor and Student Code of Conduct can be found at: http://gatortimes.ufl.edu/2018/08/20/updated-uf-student-honor-and-student-code-of-conduct/.

SOFTWARE USE:
All faculty, staff and students of the university are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against university policies and rules, disciplinary action will be taken as appropriate.

SERVICES FOR STUDENTS WITH DISABILITIES:
The Disability Resource Center coordinates the needed accommodations of students with disabilities. This includes registering disabilities, recommending academic accommodations within the classroom, accessing special adaptive computer equipment, providing interpretation services and mediating faculty-student disability related issues. Students requesting classroom accommodation must first register with the Dean of Students Office. The Dean of Students Office will provide documentation to the student who must then provide this documentation to the Instructor when requesting accommodation 0001 Reid Hall, 352-392-8565, www.dso.ufl.edu/drc/

CAMPUS HELPING RESOURCES:
Students experiencing crises or personal problems that interfere with their general well-being are encouraged to utilize the university's counseling resources. The Counseling & Wellness Center provides confidential counseling services at no cost for currently enrolled students. Resources are available on campus for students having personal problems or lacking clear career or academic goals, which interfere with their academic performance.

- *University Counseling & Wellness Center, 3190 Radio Road, 352-392-1575,* www.counseling.ufl.edu/cwc/
  - Counseling Services
  - Groups and Workshops
  - Outreach and Consultation
  - Self-Help Library
  - Wellness Coaching

- *Career Resource Center,* First Floor JWRU, 392-1601, www.crc.ufl.edu/

- UF Mindfulness: https://www.ufmindfulness.org/

RECORDINGS:

Our class sessions may be audio visually recorded for students in the class to refer back and for enrolled students who are unable to attend live. Students who participate with their camera engaged or utilize a profile image are agreeing to have their video or image recorded. If you are unwilling to consent to have your profile or video image recorded, be sure to keep your camera off and do not use a profile image. Likewise, students who un-mute during class and participate orally are agreeing to have their voices recorded. If you are not willing to consent to have your voice recorded during class, you will need to keep your mute button activated and communicate exclusively using the "chat" feature, which allows students to type questions and comments live. The chat will not be recorded or shared. As in all courses, unauthorized recording and unauthorized sharing of recorded materials is prohibited.