## Task X: Develop generalized vegetation model for simulating community dynamics

**1. Objective(s)**: Generalize existing photosynthesis-based vegetation models developed for freshwater aquatic, dune, and crop vegetation communities for use in a wide variety of aquatic and transitional vegetation communities and must include mechanisms to simulate competition and colonization by invasive species

**2. Background and Problem Description:** Vegetation communities, especially riverine and coastal wetlands, are critical elements of natural infrastructure and provide a host of benefits including habitat provisioning, carbon sequestration, flood risk management, and recreation, among others. However, these ecosystems are increasingly subject to environmental changes such as altered precipitation, runoff and snowmelt patterns, drought, floods, temperature changes, sea level change, and development pressures, among others. At the same time, increasing desire for the ecosystem goods and services provided by vegetation communities has led to increased efforts to restore and in some cases, expand expanses of native vegetation. However, the persistence and evolution of restored and managed vegetation communities under anticipated environmental changes is not well understood and few tools exist to holistically predict vegetation response. Anticipated changes in environmental conditions may affect the historical ranges of vegetation species and potentially provide additional routes for non-native species establishment. Potential restoration and maintenance interventions designed to address vegetation degradation may also affect species composition and dynamics. Adapting proven vegetation models designed for specific vegetation species or vegetation communities to apply to a broader range of vegetated ecosystems will allow USACE to better understand future with and without project conditions and monitoring and maintenance requirements for proposed projects associated not only with ecosystem restoration studies but also flood and coastal storm risk management studies and projects utilizing navigational dredged material as a sediment resource.

**3. Project Delivery Team:** C. Piercy, T. Swannack, B. Herman, E. Russ, B. Charbonneau, A. Tritinger, M. Bryant, G. Savant

**4. Value:** Improved modeling of vegetated ecosystems will allow USACE to better manage projects that utilize or rely on vegetation for function, which will improve ecosystem restoration and management, better understand management of invasive and/or non-native species, enable the use as vegetation as a component of coastal and flood risk management systems, and facilitate sustainable navigational dredged material management that includes beneficial use in and around vegetated environments.

**5. Approach:** The primary objectives of this project are to 1) develop and deliver a generalized vegetation model (GenVeg) that includes the ability to simulate invasive species colonization and competition, 2) demonstrate the integration of the model with enterprise hydrodynamic tools, and 3) demonstrate model application in the complex coastal wetland environment. Additional applications to riverine wetland environments will be demonstrated as part of *Evaluation and Modification of Vegetation Growth Model for Application in Riverine Systems*.

As part of this effort, the generalized vegetation model will be designed to be compatible with the Community Surface Dynamics Modeling System hosted by the University of Colorado. The finished model will be available through the CSDMS website and will be structured to conform with the CSDMS Basic Model Interface to allow simple coupling with other CSDMS models. To accomplish these objectives, the following tasks are required:

* Task 1: Literature search, model scope, and gap analysis – Determine the relevant environmental drivers and processes are required to include from existing vegetation models previously developed by ERDC. Determine types of vegetation to include in GenVeg (e.g. annual herbaceous, herbaceous perennial, woody perennial). Determine appropriate spatial and temporal model scales to apply to USACE projects. Determine data requirements to run and validate GenVeg.
* Task 2: Integrate and generalize existing model into GenVeg – Integrate existing ERDC vegetation models; develop a generalized approach to simulating vegetation dynamics; implement a generalized vegetation model (i.e. GenVeg) in Python and re-create prior vegetation model implementations for 1) submerged aquatic vegetation, 2) crops, and 3) dune communities.
* Task 3: Develop generalized approach using environmental drivers to modulate vegetation growth – Using conceptual model from *Evaluation and Modification of Vegetation Growth Model for Application in Riverine Systems*, adapt existing disturbance and mortality approaches to better simulate the effects of environmental drivers on vegetation growth and dieback within GenVeg; compare effects on distribution and biomass estimates for dune vegetation using modulated versus idealized vegetation growth.
* Task 4: Develop species competition modules – Assess existing competition models for applicability in GenVeg; identify applicable conceptualization of competition strategies from *Evaluation and Modification of Vegetation Growth Model for Application in Riverine System*s to include in vegetation competition model; implement competition model in GenVeg; demonstrate the effect of different approaches for native and non-native wetland species in riverine environments. Model integration with enterprise riverine hydrodynamics models such as ADH or HEC-RAS will be demonstrated.
* Task 5: Model sensitivity analysis and testing – Apply GenVeg to previous demonstration sites to elucidate model behavior under a range of conditions. Determine model parameter sensitivity, limit states, and develop fail safe checks for unstable solutions where necessary.
* Task 6: Coastal wetland case study – Apply GenVeg to existing coastal wetland site to determine efficacy in determining maintenance requirements for coastal wetlands to maintain CSRM functions. GenVeg integration with ADCIRC and STWAVE will be demonstrated. Possible locations include New Jersey back bays, Texas coast, Mobile Harbor, or Jamaica Bay.

**5. Milestones:**

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| Task | FY20 | | | | FY21 | | | | FY22 | | | | FY23 | | | |
| 1) Literature search and gap analysis |  | X | X | X | X |  |  |  |  |  |  |  |  |  |  |  |
| 2) Integrate and generalize existing model |  |  | X | X | X | X | X | X |  |  |  |  |  |  |  |  |
| 3) Vegetation growth modulation due to environmental conditions |  |  |  |  |  | X | X | X | X | X | X |  |  |  |  |  |
| 4) Species competition module |  |  |  |  |  |  | X | X | X | X | X | X |  |  |  |  |
| 5) Sensitivity analysis and testing |  |  |  |  |  |  |  |  | X | X | X | X | X | X |  |  |
| 6) Case study development |  |  |  |  |  |  |  |  |  |  | X | X | X | X | X |  |

**6. Funding:** Year 1: $145K

Year 2: ???

Year 3: ???

Year 4: ???

**7. Products:**

* JA: literature review on coastal vegetation models and relevance for management (FY 20-21) – will be delayed into Q2 FY21 due to COVID-19 hiring delay
* JA: manuscript of GenVeg development with demonstration of results for three types of vegetation systems (riverine SAV, crops, and dune vegetation) – to be submitted Q4 FY21 to *Ecological Modelling, Environmental Modelling and Software* or similar
* Model: GenVeg model base (coded in Python) and user guide submitted to CSDMS community - (expected Q2 FY22)
* JA: manuscript on the effect of environmentally modulated growth on dune vegetation simulations in GenVeg (expected Q3 FY22)
* Model: Update to GenVeg to include growth modulation including update to user manual (Expected Q1 FY23)
* JA: manuscript on implementation of competition approaches in GenVeg and the effect on invasive species dynamics among SAV communities (to be submitted Q4 FY22)
* Model: Update to GenVeg to include competition including updates to user manual (expected Q2 FY23)
* JA: Application of GenVegto proposed wetland NNBF/BUDM site with focus on realistic application to future conditions and risk of *Phragmites australis* invasion due to construction/maintenance activities (to be submitted Q3 FY23)

**8. Potential COVID-19 impacts:**

Task1 is delayed by 1 quarter due to contractor hiring delays associated with COVID19.