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Latitudinal effect on the growth dynamics of harvested stands of *Typha*: A modeling approach

Dinh Ngoc Hai*, Takashi Asaeda, Jagath Manatunge

Department of Environmental Science and Human Engineering, Saitama University, 255, Shimo-Okubo, Saitama-shi, Saitama 338-8570, Japan

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Abstract

A model was developed for *Typha*, to examine the effects of latitudinal changes in temperature and radiation on the partitioning of total biomass during the growing season into rhizomes, roots, flowering and vegetative shoots, and inflorescences.

Regardless of initial rhizome biomass, both above and belowground biomasses converge on a equilibrium value, with the balance between total production and metabolic loss being latitude-specific. If aboveground biomass is harvested just once, then both above and belowground biomasses return to equilibrium values after several years. If the aboveground biomass is harvested annually, then both above and belowground biomasses converge on smaller equilibrium values, which are determined by the balance between the sum of production prior to harvesting and after harvesting, and the sum of annual metabolic losses and a loss due to harvesting.

The model could be used in wetland management activities to predict the potential growth of *Typha* in given conditions as well as the responses of *Typha* stands to harvesting over a wide range of latitudes for times ranging from a season to several years.

Keywords: equilibrium biomass; harvesting; latitudinal effect; modelling; *Typha*

1. Introduction

Typha species are rhizomatous perennial plants, occurring in seepage areas, swamps and billabongs over a wide latitudinal range. Once having being considered weeds, the plants are now drawing favorable attention in various engineering fields, such as wetland management (Sale and Wetzel, 1983) and sewage treatments (Coveney et al., 2002).

Although *Typha* is widely distributed from cold to tropical zones, its productive or morphological characteristics are strongly influenced by the meteorology of the site (McNaughton, 1966). This can be partly attributed to different rates of photosynthesis (Knapp and Yavitt, 1995) and respiration, and partly to climatic differences in resource translocation to belowground organs (McNaughton, 1966; Asaeda et al., 2005).

Under favorable conditions, *Typha* achieves high growth rates and sometime can invade and block drainage and supply ditches, cause various problems in rice paddies, and reduce plant diversity in wetlands. Harvesting is considered as a method to control the over-growth of *Typha* stands in wetland management activities (Beule, 1979). Some authors reported the most effective time of cutting is when belowground reserves are at their lowest level, typically when the flowering spike is growing (Sale and Wetzel, 1983). Other authors suggested that regrowth depends on environmental conditions such as climate (Shekhov, 1974; Ulrich and Burton, 1985).

Most of these studies, however, are based on empirical analyses, and focus on a particular phenomenon under limited conditions rather than taking a broad scale and whole-plant perspective. This can make it difficult to generalize and to understand within-plant integration and how this might vary in response to environmental drivers such as temperature and solar radiation.

* Corresponding author.
E-mail address: haidnhn@yahoo.com (D.N. Hai).

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In contrast, a mechanistic growth model can synthesize quantitative information about physiological processes and thus provide estimates of ecological, physiological, or morphological responses which may otherwise be hard to measure (Asaeda and Karunaratne, 2000; Asaeda et al., 2005). To study the interaction between above- and belowground components, it is essential to understand the mechanism of material allocation to each organ, for which mechanistic modelling based on the material conservation is useful.

This study aimed to develop a mechanistic growth model of *Typha* spp. and to use it to examine the latitudinal effect on the growth dynamics and the response of *Typha* to harvesting under different climate conditions.

2. The growth model of *Typha*

2.1. Model description

In this study, biomasses of aboveground organs (leaves, peduncles and flowers) and belowground organs (roots, 2-year old rhizomes, 1-year old rhizomes, and new rhizomes), quantified in grams of dry weight per square meter, were separately formulated to account for the energy gain and loss (photosynthetic production, respiration and mortality, inter-organ transport to and from each organ) (Fig. 1).

Phenology of a plant population and its development phase are quantified by its morphological appearance and physiological age. The development phases, which include emergence of shoots, inflorescence formation, maturation and senescence (Linde et al., 1976; Garver et al., 1988), do not only depend on chronological age, but also on several environmental factors such as temperature, availability of resources or disturbances.

The starting time of shoot growth in spring depends on the local condition, such as day 110 (McNaughton, 1966), day 133 (Garver et al., 1988), day 100 (Smith et al., 1988) for *Typha latifolia*; and day 120 (McNaughton, 1966), day 133 (Garver et al., 1988), day 60 (Hill, 1987) for *Typha angustifolia*. By plotting these values the starting day, y, was determined as a function of latitude, x:

$$y = -0.0011x^3 + 0.1182x^2 - 1.7902x + 58 \quad \left(R^2 = 0.83\right). \tag{1}$$

Days of phenological events are estimated from the starting time of shoot growth and are summarized in Table 1.

2.2. Governing equations

The net growth of each fraction of a plant is the result of photosynthesis, respiration and mortality losses, and translocation between organs, as follows.

$$\frac{dB}{dt} = G - R - D + \sum \mathrm{Tr} \tag{2}$$

where, B, G, R, D, and $\sum \mathrm{Tr}$ are the biomass, gross photosynthesis rate, respiration rate, mortality rate and inter-organ translocation, respectively. Therefore, given in grams dry weight, and stratifying the aboveground organs into one cm thick horizontal layers, the following equations describe the material budget for each organ or each layer of *Typha*.

For n-year old rhizomes ($n = 0$, 1, 2 are the age of rhizomes).

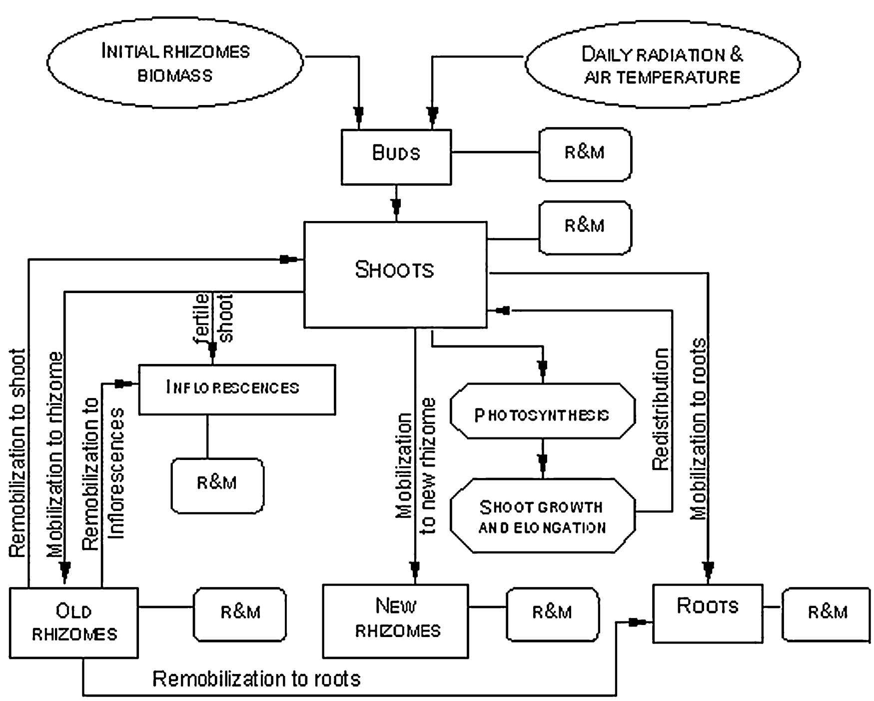

Fig. 1. Flow diagram for the model. R&M is respiration and mortality loss.