Modeling Crop Losses

In this short introductory section we want to ask ourselves: what is the use of simulation modeling in crop loss understanding and analysis? But before moving into the field of crop loss modeling, we need to point out a few elements.

- Production situations differ widely across world agroecosystems and are undergoing unprecedented changes (Dyson, 1999; WRI, 2005). One definition for 'production situation' refers to a hierarchy of constraints to crop production: from production level 1, where no limit to crop growth occurs, and is defined only by radiation and plant genotype; to production level 2, where some water shortage occurs at least for some time of the growing season; to production level 3, where a shortage of nitrogen may also occur; and to production level 4, where the above limiting factors are compounded by shortages of phosphorus and/or potassium (Penning de Vries, 1982; Rabbinge et al., 1989). While this first definition focuses on crop production, another, holistic definition of a production situation is the 'body of environmental factors — physical, biological, social, and economic — where agriculture takes place' (De Wit, 1982). While both definitions have value, the latter enables one to link attainable yields to production situations, as well as to human components such as farmers' skills, socio-economic factors, and available techniques for future improvement (Van Ittersum and Rabbinge, 1997), and decisions (McRoberts et al., 2011).
- Crop losses caused by diseases, animal pests, and weeds, range between 20 to 40% of the yield that would be attained otherwise (e.g., Savary et al., 2005; Oerke, 2006), depending on the production situations. This obviously represents a massive challenge to food security and food safety, and cannot be ignored.
- Why do we address epidemiological and crop loss modeling in separate sections in this module? There are four reasons for this.
    1. First, the linkage between epidemics and crop losses is that of a growing crop. This implies that we shall need to consider some basic agrophysiological principles.
    2. A second reason is that the linkages epidemics-crop losses, on the one hand, and crop losses-economic losses, on the other hand, are non linear. The relationships between epidemics and crop losses are represented by damage functions, while the relationships between crop losses and economic losses are governed by loss functions (Zadoks, 1985). Thus, the translation of epidemics into crop losses is not direct, and in fact, is quite complex.

3. A third reason is that we want to keep our models as simple and tractable as possible: we want to model for a purpose (Loomis et al., 1979): epidemics on the one hand, crop losses on the other. Linking the two implies complex feed-backs and feed-forwards, which, despite their relevance, would detract us from our main objective of providing introductory working elements to the topic.
4. Lastly, when thinking of crop losses, other harmful agents must be considered in addition to plant pathogens: animals (especially insects and spiders), and weeds. As a result, the analysis of crop losses entails the consideration of injuries caused by an array of crop harmful organisms. We shall see in the following chapters that considering so many different organisms does not lead to increased complexity.

- Crop losses — not epidemics — are the basis for disease management. As a result, the last three elements of the above imply a crucial issue: understanding and modeling crop losses is not easy. In particular, thresholds for decisions, whether strategic (before a crop is being established) or tactical (when the crop is standing) are not static, but variable (Zadoks, 1985; Rabbinge et al., 1989). One of the several causes for threshold variation is the considered production situation.
- Both damage and loss functions are highly variable (e.g., Zadoks, 1985; Savary et al., 2000), for a number of reasons, among which are (1) the nature of the harmful organism, and (2) the considered production situation (and therefore, the considered attainable, uninjured, yield). What follows does not dwell on this important topic. Simulation modeling, however, can be seen as one tool to address it.

Much of what will be developed in the following chapters is derived, with some expansion, but also some simplifications, from the book by Rabbinge et al. (1989). As in the previous chapters, our aim is to bring forward ideas and methods that can be implemented with ease, and we shall try to provide frameworks that are as simple as possible.

Let us try, at least temporarily, to answer the question we posed at the beginning of this introduction. Simulation modeling in crop loss analysis is useful in at least two important areas: one is to produce estimates of likely crop losses caused by one (sometimes several) yield reducers; another is to assess and rank the importance of yield reducers in terms of crop losses. There are other possible applications of simulation modeling. One potential application, which was widely shared when simulation modeling was new to the field of plant protection, was that it could become a tool to guide crop protection. There has been accumulating evidence, however, that this approach was unlikely to bear fruit for a number of reasons (e.g., Butt and Jeger, 1985;

Jeger, 2000). Conversely, much simpler approaches based on very solid science could be far more successful, such as the EPIPRE program (Zadoks, 1989).

The second area where simulation modeling is a powerful tool is that, being process-based, it enables one to not only address "what has been lost", but also what could be gained. In other words, the approach enables one to explore scenarios where new crop health management approaches (e.g., new genotypes, different crop rotations) would be implemented. This is possibly the most exciting reason for using simulation modeling in this area.

References

Butt, D. J., and Jeger, M. J. 1985.The practical implementation of models in crop disease management. Pages 207-230 in: Advances in Plant Pathology, vol. 3. C. A. Gilligan, ed. Academic Press, London.

Dyson, T. 1999. World food trends and prospects to 2025. Proc. Natl. Acad. Sci. USA 96:5929-5936.

van Ittersum, M. K., and Rabbinge, R. 1997. Ecology for analysis and quantification of agricultural input-output combinations. Field Crops Res. 52:197-208.

Jeger, M. J. 2000. Bottlenecks in IPM. Crop Prot. 19:787-792.

Loomis, R. S., Rabbinge, R. and Ng, E. 1979. Explanatory models in crop physiology. Annu. Rev. Plant Physiol. 30:339-367.

McRoberts, N., Hall, C., Madden, L. V., and Hughes, G. 2011. Perceptions of disease risk: from social construction of subjective judgments to rational decision making. Phytopathology 101:654-665.

Oerke, E. C. 2006. Crop losses to pests. J. Agric. Sci. 144:31-43.

Penning De Vries, F. W. T. 1982. Systems analysis and models of crop growth. Pages 9-19 in: Simulation of Plant Growth and Crop Production. F.W.T. Penning de Vries, and H. H. Van Laar, eds. Pudoc, Wageningen.

Penning De Vries, F. W. T., and Van Laar, H. H., eds. 1982. Simulation of Plant Growth and Crop Production. Pudoc, Wageningen.

Rabbinge, R., Ward, S. A., and Van Laar, H.H., eds. 1989. Simulation and Systems Management in Crop Protection. Pudoc, Wageningen.

Savary, S., Willocquet, L., Elazegui, F. A., Castilla, N. P., and Teng, P. S. 2000. Rice pest constraints in tropical Asia: quantification of yield losses due to rice pests in a range of production situations. Plant Dis. 84:357-369.

Savary, S., Teng, P. S., Willocquet, L., and Nutter, F. W., Jr. 2005. Quantification and modeling of crop losses: a review of purposes. Annual Review of Phytopathology 44:89-112.

de Wit, C. T. 1982. L'analyse des systèmes de production primaires. Pages 275-283 in: La Productivité des Pâturages Sahéliens. Une Etude des Sols, des Végétations et de l'Exploitation de cette Ressource Naturelle. F.W.T. Penning de Vries and M. A. Djiteye, eds. Agricultural Research Report 918, Pudoc, Wageningen.

World Resource Institute. 2005. Millenium Ecosystem Assessment: Ecosystems and Human Well-Being - Synthesis. Island Press, Washington, D.C.

Zadoks, J. C. 1985. On the conceptual basis of crop loss assessment: the threshold theory. Annu. Rev. Phytopathol. 23:455-473.

Zadoks, J. C. 1989. EPIPRE, a computer-based decision support system for pest and disease control in wheat: its development and implementation in Europe. Pages 3-29 in: K. J. Leonard and W. E. Fry, eds. Plant Disease Epidemiology, vol. 2, Genetics, Resistance, and Management. McMillan, New York.

Suggested reading

Cassman, K. G., and Woods, S., Coordinating Lead Authors. 2005. Cultivated Systems. Pages 741-789 in: Ecosystems and Human Well Being, Millenium Ecosystem Assessment, Current State and Trends, Vol. 1. Island Press, Washington, D.C.

Evans, L. T. 1998. Feeding the Ten Billions. Plants and Population Growth. Cambridge University Press, Cambridge.

Rossing, W. 1991. Simulation of damage in winter wheat caused by the grain aphid Sitobion avenae. 2. Construction and evaluation of a simulation model. Neth. J. Plant Pathol. 97:25-54.

Rossing, W. 1991. Simulation of damage in winter wheat caused by the grain aphid Sitobion avenae. 3. Calculation of damage at various attainable yield levels. Neth. J. Plant Pathol. 97: 87-103.

Rossing, W. 1993. On damage, uncertainty and risk in supervised control. Aphids and brown rust in winter wheat as an example. PhD Dissertation, Wageningen Agricultural University.

United Nations Environment Program, 2007. GEO4 - Global Environment Outlook: Environment for Development. Progress Press, Malta.