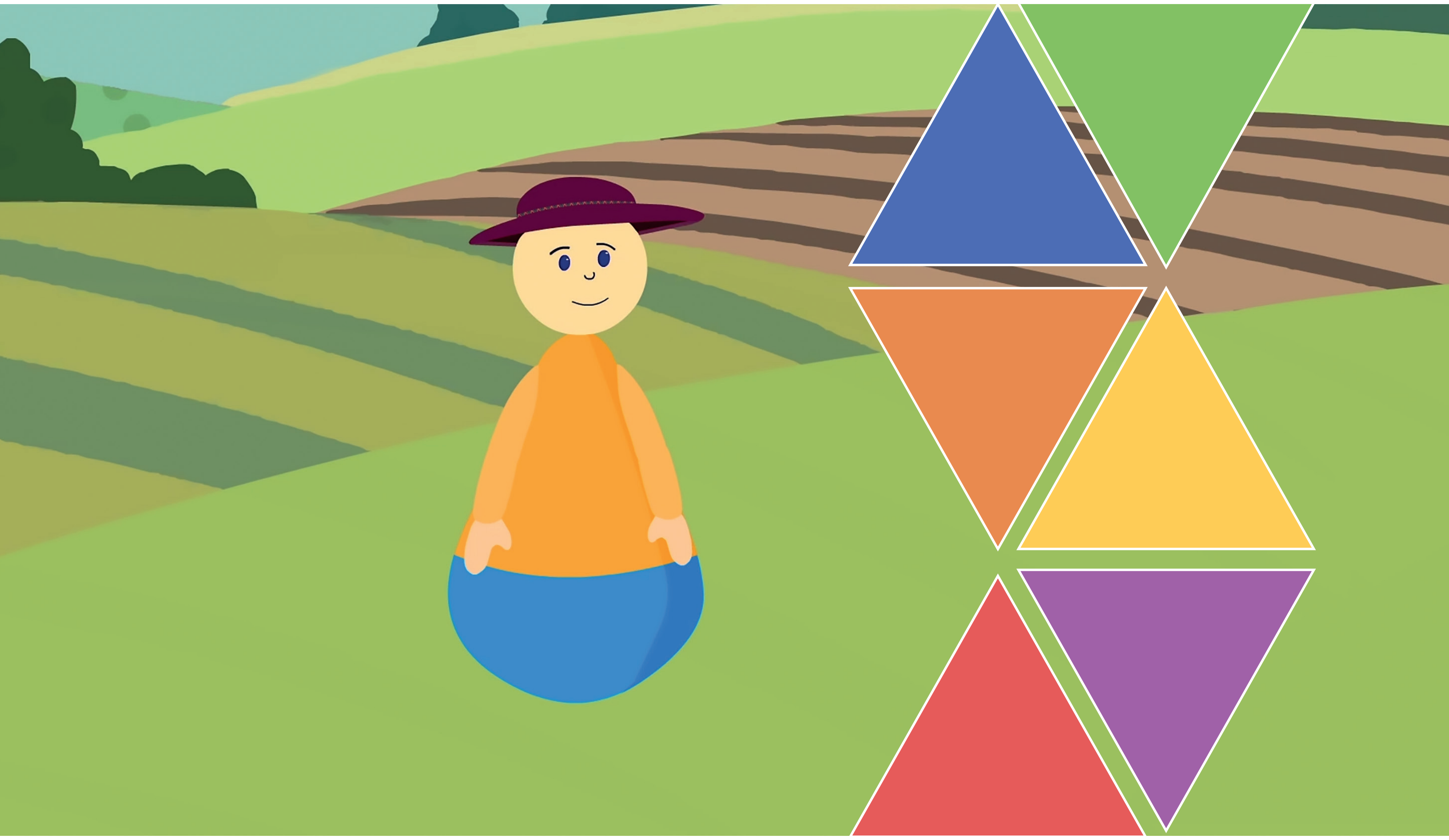
RolyPolyModel

Resilience of Agricultural Ecosystems Principle at Farm Level Technical Summary



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Resilience of Agricultural Ecosystems – The Skipjack or Roly-Poly toy Modell

Stephan Pabst; FH JOANNEUM

Resilience of agro-ecosystems is a core issue in modern agriculture. To maintain soils stable and functional, numerous factors need to be kept in balance. Keeping track of all relevant factors and functions is a major challenge. Educators in agriculture and ecology can use the roly-poly toy as a teaching aid to visualize and experiment with the interrelationships.
Watch our 'Explainity' (explanatory video) for an idea of how the Skipjack or Roly-Poly toy can be used as a tool to illustrate agroecosystem resilience. This article reviews the background literature and the concept of soil -resilience. The main functions of soil are addressed and examples of management actions that positively or negatively influence resilience are given.

Resilience

The concept of resilience is widely used across disciplines, including social sciences (psychology, management studies, etc.), technology and mechanical engineering (material properties, networks, etc.) or ecology (climate, soil, etc.). Ecological resilience refers to the maintenance of functions that are, unlike in mechanical engineering not to one but several equilibrium stages.
A term used for ecological systems is „adaptive cycles". Adaptive cycles are best represented by a double loop (cf. Ludwig et al. 2018). In agro-ecosystems, they occur at different scales and levels. While in this example we focus on arable land, resilience may be observed at all levels. The choice of the Roly-Poly toy as a model is inspired by a research paper on resilience at farm level. For further information, see Background Paper 2.

Soil Resilience

The term 'soil resilience' describes the ability of a soil to change under destabilizing influences to remain functional. Soil undergoes several phases of change throughout the year:

- Cultivation: rapid colonization of disturbed areas by pioneer plants.
- Conservation: slow build-up and „storage" of material and energy.
- Structural collapse and release of potential
- Reorganization (composting and release of nutrients).

The functionality of soils is reflected at three levels:

a. Past management (soil memory)
b. Current status (pressures and disturbances)
c. Recommendations for future holistic management

This can best be explained using the example of arable land that...

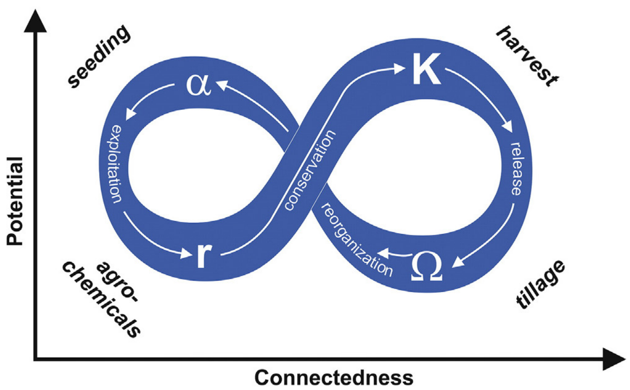

Figure 1: Adaptive cycle of soil (Ludwig et al. 2018)

a. has been impacted in the past with heavy equipment and tires that are too small or too hard (Figure 3). This caused soil compaction and subsequently a limited the rooting potential (Figure 4) and reduced water absorption capacity.
b. Due to compaction the soil cannot absorb the water masses from current, heavy rainfall (Figure 5). This can lead to topsoil erosion (Figure 6), especially on slopes (Figure 7).
c. In the future, compaction can be not only eliminated but also prevented through holistic management. Such measures may include ridge planting, intercropping with deep-rooted plants (e.g. red clover, field bean or alfalfa) (Figure 8, Figure 9), ground cover, mulch sowing (Figure 10, Figure 11) and using lighter equipment, minimization of cultivation steps or soil-conserving cultivation methods (such as on-land ploughing, Figure 12).

A theoretical model describes two so-called traps for systems of arable land. Soil compaction appears in the model in the double loop at the bottom left in the 'poverty trap'. This means that the potential of the soil to regenerate is limited and the degradation or compaction.
Another 'trap' is the 'rigidity trap'. Highly specialized varieties or fertilizers and the application of pesticides have created a very rigid framework in which the system operates. Soil's potential is maintained at a high level by high external input and there is no interconnection with other soil factors. Upon failure of individual functions in the high performance system, the entire production will collapse.
Sustainable soil management has mostly been defined by efficiency of resource use. This approach however is insufficient and even counterproductive as long as only the short-term perspectives are taken into account. Soils in agroecosystems are systems that often respond in unpredictable ways, and human management creates additional pressures and disturbances. This further increases uncertainty. Therefore, soils need to be managed in an adaptive manner that allows for the soil to regenerate to increase resilience (cf. Ludwig et al. 2018).

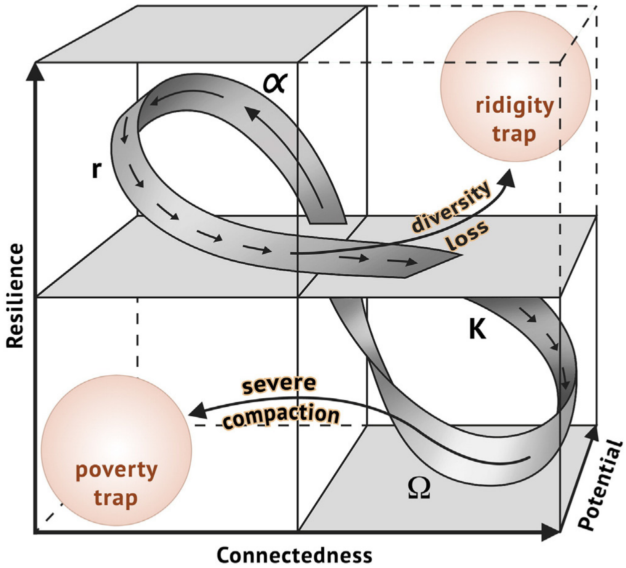

Figure 2: Poverty and rigidity traps reduce the potential of the soil to renew itself independently, in both cases resilience is low (vgl. Ludwig et al. 2018).

Reference: Ludwig, M.; Wilmes, P. und Schrader, S. (2018)
Measuring soil sustainability via soil resilience. Science of the Total Environment, 626, 1484-1493.
https://doi.org/10.1016/j.scitotenv.2017.10.043

Appendix: Questions for teaching; Figures 3-12 and List of Figures.

Questions and suggestions for teaching:

- Which management actions are positive and which are negative for soil resilience?
- How many measures with positive-impact needed? What are they?
- How many measures with negative-impact can the soil system withstand and still resilient?
- What kind of impacts destabilize the system?

Figures:

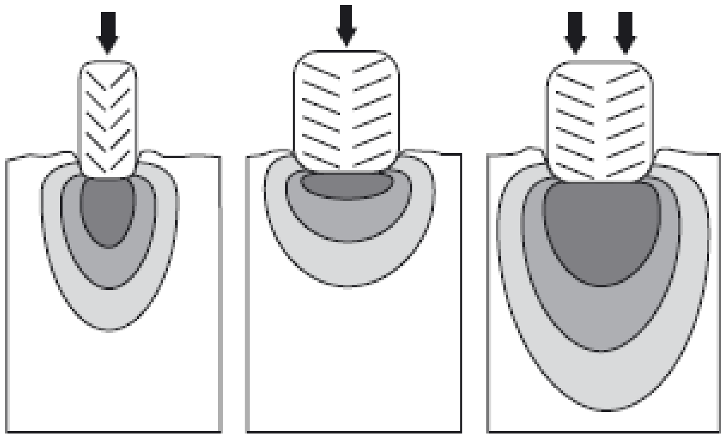

Figure 3: Different range of soil compaction depending on tire shape or pressure and weight. Merkblatt Bodenverdichtung Nordwestschweiz 2005, Bildnachweis: U.W. Flück nach R. Brandhuber und PTG GmbH

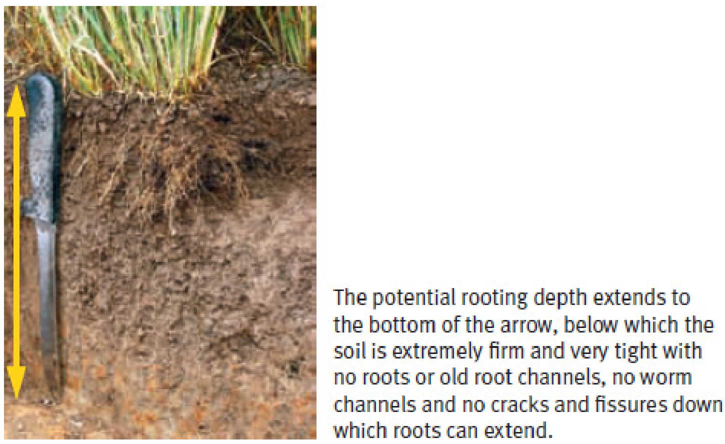

Figure 4: Soil density and potential for rooting depth may be determined in the soil profile by number and distribution of root canals, cracks, and earthworm tunnels FAO (2008) VISA – Visual Soil Assessment Guide. Verfügbar unter: http://www.fao.org/3/i0007e

Figure 5: Soil compaction 2018,
Aus: https://www.bauernzeitung.ch/artikel/bodenverdichtung-mutter-erde-vergisst-nur-langsam; Bild Thomas Keller, Agroscope

Figure 6: Water erosion Detail Präsentation Grundbodenbearbeitung, Stefan Waldauer; Raumberg Gumpenstein 2018

Figure 7: Water erosion Präsentation Grundbodenbearbeitung, Stefan Waldauer; Raumberg Gumpenstein 2018

Figure 8: Undersowing clover in grain. Bioaktuell.ch 2018
https://www.bioaktuell.ch/pflanzenbau/ackerbau/getreide/getreide-anbautechnik/untersaat-in-getreide.html

Figure 9: Mixed sowing with broad bean.
Aus: Zwischenfruchtanbau zum Erosions- und Gewässerschutz, LfL Bayern 2018.

Figure 10: Mulch sowing after 100 mm of constant rain withour soil erosion.
Aus: Zwischenfruchtanbau zum Erosions- und Gewässerschutz, LfL Bayern 2018.

Figure 11: Under_cover, Originaltitel: Cornell-DS-Soja-Klein-2_under_cover, abgerufen von http://www.bodenfruchtbarkeit.net/wp-content/uploads/2016/08/Cornell-DS-Soja-Klein-2.jpg [22.5.2018]

Figure 12: On-land plough. Präsentation Grundbodenbearbeitung, Stefan Waldauer; Raumberg Gumpenstein 2018

List of figures

Figure 1: Adaptive cycle of soils (Ludwig et al. 2018) 2

Figure 2: Armuts- und Starrheits Falle binden das Potential des Bodens sich selbst-ständig zu erneuern, in beiden Fällen ist die Resilienz niedrig (vgl. Ludwig et al. 2018). 3

Figure 3: Unterschiedliche Reichweite der Bodenverdichtung abhängig von Reifenform bzw. Reifendruck und Gewicht. Merkblatt Bodenverdichtung Nordwestschweiz 2005, Bildnachweis: U.W. Flück nach R. Brandhuber und PTG GmbH 4

Figure 4: Die Bodendichte bzw. das Potential der Durchwurzelungstiefe kann im Bodenprofil anhand der Häufigkeit von Wurzelkanälen, Rissen und Wurmlöchern bestimmt werden. FAO (2008) VISA – Visual Soil Assessment Guide. Verfügbar unter: http://www.fao.org/3/i0007e 4

Figure 5: Bodenverdichtung 2018, Aus: https://www.bauernzeitung.ch/artikel/bodenver-dichtung-mutter-erde-vergisst-nur-langsam; Bild Thomas Keller, Agroscope 5

Figure 6: Wassererosion Detail Präsentation Grundbodenbearbeitung, Stefan Waldauer; Raumberg Gumpenstein 2018 5

Figure 7: Wassererosion_ Präsentation Grundbodenbearbeitung, Stefan Waldauer; Raumberg Gumpenstein 2018 5

Figure 8: Untersaat Klee Einsaat in Getreide_Bioaktuell.ch 2018 https://www.bioaktuell.ch/pflanzenbau/ackerbau/getreide/getreide-anbautechnik/untersaat-in-getreide.html 6

Figure 9: Mischsaat mit Ackerbohne_Aus: Zwischenfruchtanbau zum Erosions- und Gewässerschutz, LfL Bayern 2018. 6

Figure 10: Maismulchsaat nach 100 mm Dauerregen, keine Bodenerosion. Aus: Zwischenfruchtanbau zum Erosions- und Gewässerschutz, LfL Bayern 2018. 6

Figure 11: Under_cover, Originaltitel: Cornell-DS-Soja-Klein-2_under_cover, abgerufen von http://www.bodenfruchtbarkeit.net/wp-content/uploads/2016/08/Cornell-DS-Soja-Klein-2.jpg [22.5.2018] 7

Figure 12: On-land Pflug Präsentation Grundbodenbearbeitung, Stefan Waldauer; Raumberg Gumpenstein 2018 7

The Roly-Poly Principle at Farm Level[1]

Stephan Pabst; FH JOANNEUM

What type of farmer am I? Farming primarily cares about hectares, yields and contribution margins. Still, all farmers develops their own style. While factors, such as soil type, climate, accessibility, dictate what is possible, there still may be very different farms in the very same location. Each farmer has his or her own personal experience, family situation, social network or his or her own taste and preferences. A marketing concept that is suitable for one farm might fail for another. Often the results are a question of personal management style. The characteristics of the arm, farm operators and the environment influence each other in the farm system. The farm is characterized by its soil, its livestock, buildings and machines, liquidity and the surrounding agricultural ecosystem. Important environmental factors are location, climate conditions, politics, markets and networks. Farm operators are influenced by their families, the farm's history, their knowledge and skills, values and preferences, and current projects.

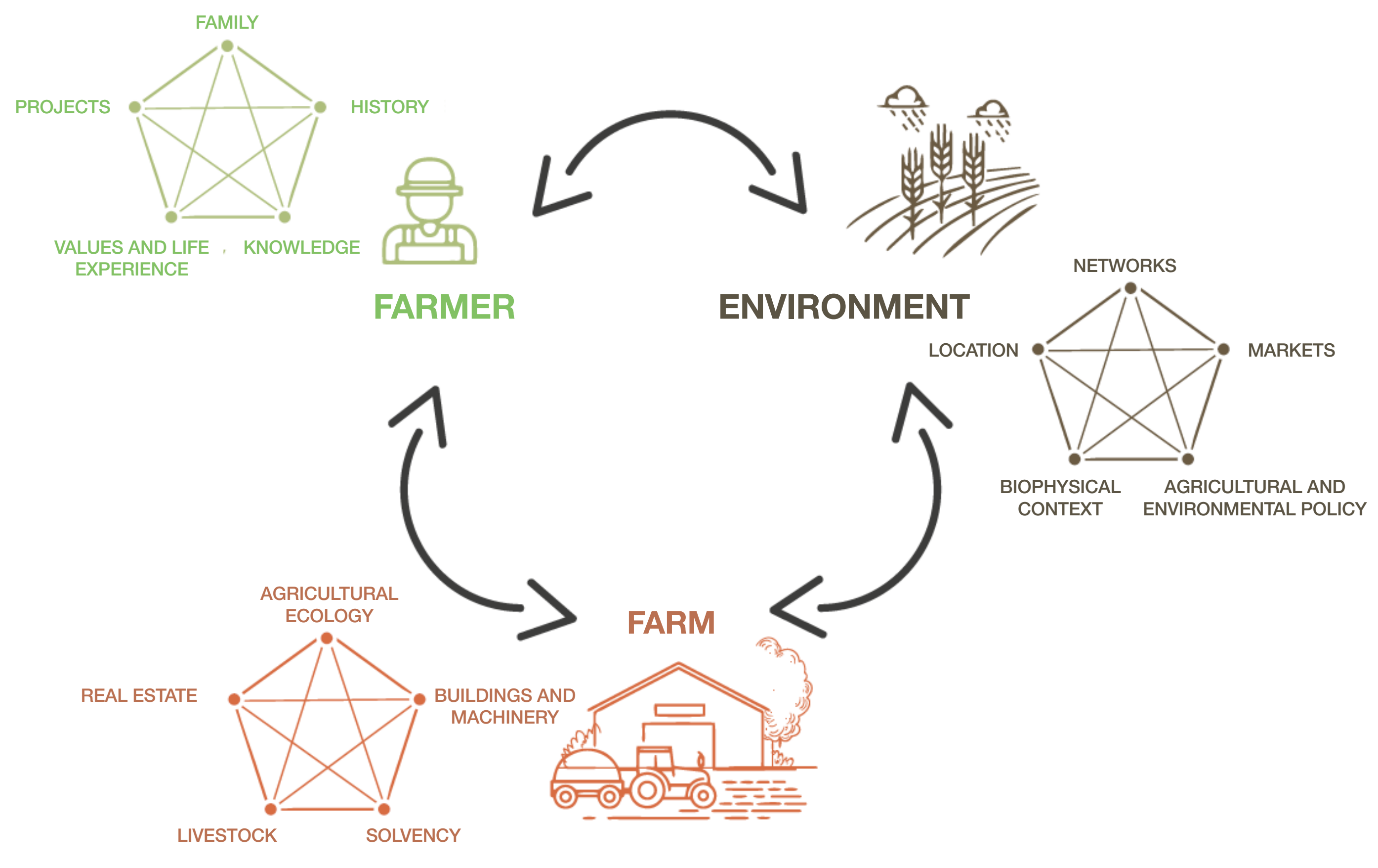

Fig. 1: The Farm as a system, translation by the author. The figure modified from Darnhofer et al. 2012

[1] Abbreviated version, first published in: Seebacher, U.; Lüking, T.; Pötsch, N.; Pabst, S.; Rehorska, R.; Weinrauch, S. (2018) Kleinbauernhof im 21. Jahrhundert. Verlag der FH JOANNEUM Gesellschaft mbH, Graz. Verfügbar unter: http://bizepaper.fh-joanneum.at/eBooks/Bauernhof-21.pdf

The Concept of Farming Styles

Agricultural sociologist Jan Douwe van der Ploeg of Wageningen University (NL) developed the concept of farming styles. Using the example of Frisian dairy farmers, van der Ploeg showed that farms develop differently despite similar conditions. In 1969, aiming for modernization, it was assumed that all farms had to develop towards more growth and automation. Empirical studies of real changes up to the 1990s, however, found different developments. Not only farms that put a focus on growth stayed successful. Farmers who did not expand their operations but diversified and relied on more manual labor were able to continue farming successfully. Sometimes they even generated a higher income than farms that were growing (see Ploeg van der 1990, 2003 and 2010). With their own, specific way of farming, farmers occupy certain positions in the symbolic, social and material space.

Farming styles and small-scale agriculture in Austria

A study on farming styles covering 1945-1980 (Langthaler 2012) showed why small family farms lasted longer in Austria compared to other European countries. Many farm managers did not trust modernization and put priority on the farm's stability as opposed to generation of short-term profits. The "Roly-Poly" principle (Langthaler 2012), see Fig. 2. illustrates that a farm's resilience depends on where the farmer sets the focus: on „autonomy" (bottom) or „dependence on the market" (top). Specialization on a single crop or product and high dependence on externally

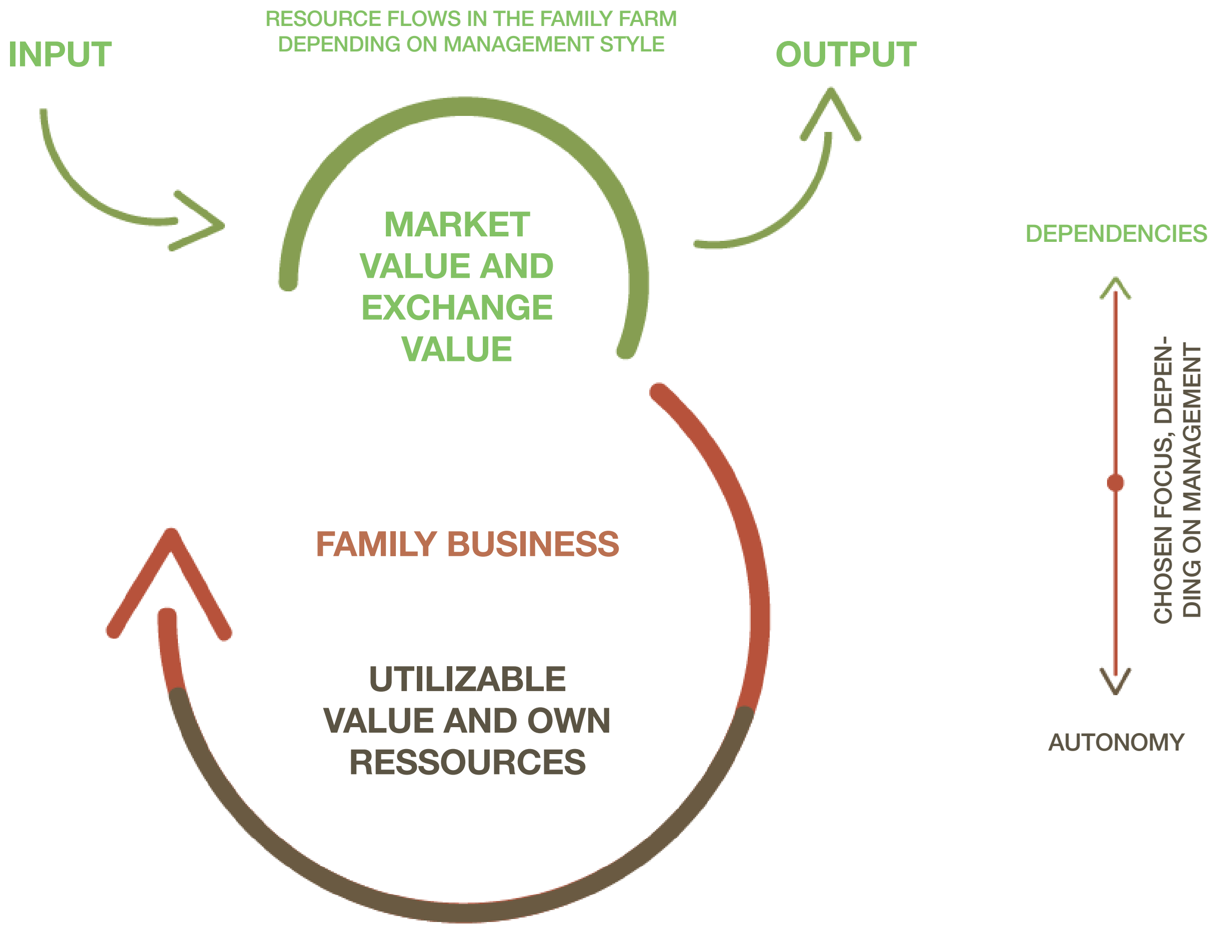

Figure 2: Resilience of an agricultural enterprise depending on its resource base. Translation by the author and modified figure after Langthaler 2012.

purchased inputs (e.g., fertilizer, feed, seed, etc.) reduces a farm‘s resilience to crises such as extreme weather events, price crashes, or epidemics. Internal production cycles and low dependence on external input, in turn, make farms more resilient to unexpected events or shocks.

Farming in your own style

The small farmer determines operations and forms of management, chooses which crops are grown, how they are processed and marketed. The operators themselves decide on their work input into agriculture, with whom and how they live and when to retire. While this may seem obvious it is not. According to the concept of farming styles there is no such thing as „the farm“ but rather as many different options as there are farmers in a given location. Thus, the Farming Styles concept contradicts the predominantly economic view of an ideal farm concept for each location and that this concept has has to be optimized depending on the owner’s risk appetite in order to survive.
Different types of farming styles can be distinguished, depending on the view taken. The consideration of types of management or the personal value agriculture has for farmers may lead to descriptions that address“innovative investing“, „continuing despite difficulties“ or „promoted specialization“ or less clichéd attributions (such as modern, progressive, outdated) (cf. Garstenauer et al. 2010).

Reference:

Darnhofer; Ika (2012) Farming Systems Research: an approach to inquiry. Veröffentlicht in I. Darnhofer, D. Gibbon, and B. Dedieu (Herausgeber): *Farming Systems Research into the 21st Century: The New Dynamic. Springer Science + Business Media Dordrecht.*

Garstenauer, Rita, Kickinger, Sophie; Langthaler, Ernst und Schwarz, Ulrich (2010). *Landwirtschaftsstile: Theorie, Methoden, Quellen. Artikel im Rahmen des Projekts Landwirtschaftsstile in Österreich 1930-1980.*

Langthaler, Ernst (2012). Balancing Between Autonomy and Dependence Family Farming and Agrarian Change in Lower Austria, 1945–1980. *Rural History Working Papers 10, Institut für Geschichte des ländlichen Raums, St. Pölten.*

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Ploeg van der, Jan Douwe (2003). *The Virtual Farmer. Past, present and future of the Dutch peasantry. Royal van Gorcum, Assen.*

Ploeg van der, Jan Douwe (2010). *Farming Styles Research: The State of the Art. Keynote lecture in Melk, Austria, 21-23. October.*

The Roly-Poly3.0[1] Resilience model for Systemic Thinking in Agro-ecology

Co-Constructors: Stephan Pabst und David Schneider

(FH JOANNEUM Graz, IAP)

Figure 1: First wood-crafted prototype

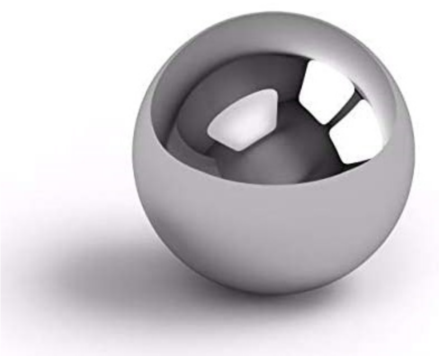

Figure 2: Steel ball 13mm we use as weights

It all began with the idea to build a physical model for resilience, which looked like the one shown in our 'explainity' developed in the Agri-Train project. My colleague David, who is skilled in woodturning, made the beautiful first prototype (Figure 1).

We soon realized that it is not that easy to make a roly-poly that, unlike a kid's toy, can be "programmed" by weights. The first prototype worked, but as soon as we put weight (Figure 2) in the hollow upper part, it would just fall over and never get up again, no matter how many weights were added at the bottom.

Therefore, to to make it as realistic as possible we came up with a printable 3D-model (Figure 5), that has an adjustable platform between the upper, cone-shaped part and the bottom, hemispherical part (Figure 3). You start by adjusting this platform (Figure 4) to allow for a different number of weights in the bottom or to use bigger weights.

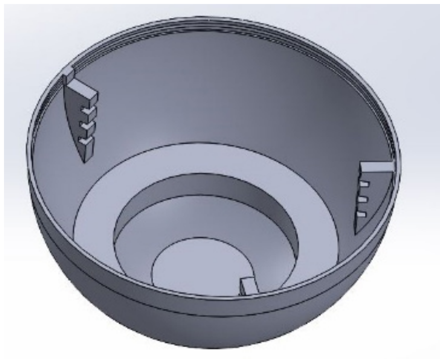

Figure 3: Newest version of the printable 3D-model „Stehaufmanndl3.0"

For example in a soil that consists mostly of heavy clay, there are fewer management options compared to a soil that is richer in sand or silt. Therefore, by changing the height of the platform you can adjust the type of soil and limits to management.

In the conus, there is an adjustable slope (Figure 6), that also allows adjusting the vulnerability of the system. The steeper the slope is, the less weights is needed for the the roly-poly to topple over.

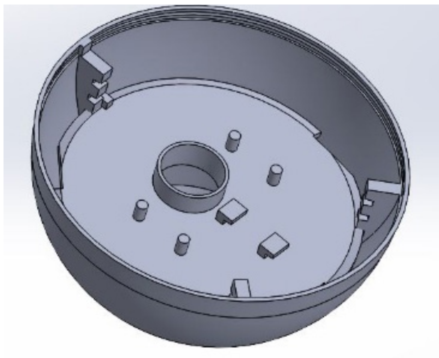

Figure 4: The bottom hemisphere of the "Stehaufmanndl3.0"

For example: If you have a nice and deep grounded blacksoil without plowing horizon your soil system is much more likely to adapt to changes, than a very shallow pseudogley. So with the degree of the slope you can adjust how tolerable the soil system is and how vulnerable it is to changes.

[1] The Roly-Poly3.0 or Stehaufmanndl3.0 has a creative commons licence (CC BY-NC-SA): Non commercial use, share alike, give appropriate credit to the licensor (us, FH JOANNEUM and Agri-Train Project).

After we found out how to adjust the roly-poly to different systems, we wanted to see how we could program it with management measures that make it more robust towards shocks on either end. One arm is the bottom-side (+) and the other leads to the top side (-). If we put 1 weight in the bottom, we do not observe a strong roly-poly effect. We can put up to 5 weights in the bottom, until it becomes resilient to shocks (i.e. attempts to knock it down).

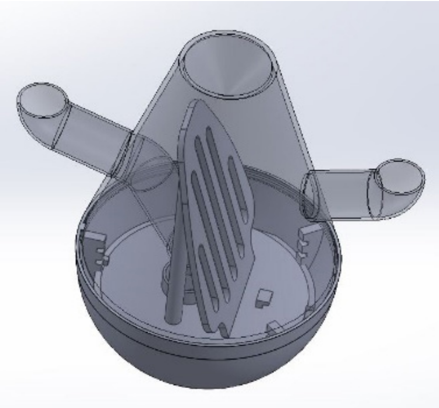

Figure 6: Insight view of the „Stehaufmanndl3.0" with adjustable slope in the conus.

We think that this is quite realistic – we can say that 1-5 represent the basic management procedures needed in arable farming. If you chose them wisely, you get a resilient soil-system. If one or two of your basic management methods are not appropriate for the type of soil or which climate, they add weight to the top and will contribute to bringing your roly-poly down.

So, you like the roly-poly resilience model and want to try it out and use it in class or training? There are three options:

Figure 5: Neueste Version des 3D-druckbaren „Stehaufmanndl3.0"

1. If you are a skilled wood turner, you make it yourself following the 3D-Model.
2. If you prefer to let machines do this job for you, just send the 4 parts of the model to your trusted 3D-Printer.
3. You can order a wood crafted version from David Schneider ;)

One last note: The head needs to be very light and instead of 3D-printing it, we used a regular ping pong ball. Just make sure your Roly-Poly does not stay headless.
We are looking forward to hear from you, which experiences you make or if you have new ideas to improve the roly-poly. The 3D-Model has a creative commons licence (CC BY-NC-SA) for non-commercial use, as for example in teaching. Feel free to improve it and adapt it to your needs – we and our institution just love to be mentioned!

Feel free to write us an E-mail:

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Thank you! Without the precious ideas and inputs and "go ahead attitude" of you, the physical Roly-Poly model would have never been realized: Agri-Train Project Team (Inge, Yvonne and Sylvana), Johannes Haas, Dietrich Landmann, Veronika Hager, Wolfgang Weiß, Franz Auer. Thank you!

Sources:

Figures 1, 3-6: © David Schneider;
Figure 2: https://images-na.ssl-images-amazon.com/images/I/31091Aoyl8L._AC_.jpg