# EXTENDED ABSTRACTS OF GIPP

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GERAN INSENTIF PENYELIDIKAN UNTUK PENGAJARAN DAN PEMBELAJARAN

(INCENTIVE RESEARCH GRANT FOR TEACHING AND LEARNING)

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# DEVELOPMENT OF A SPREADSHEET SOFTWARE FOR STUDENTS WHO ARE NON-COMPUTER PROGRAMMERS TO BUILD AND RUN MATHEMATICAL MODELS

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**ABSTRACT**
Microsoft Excel requires the least proficiency in computer programming compared to other programming platforms. The software, however, has several weaknesses: it does not directly support loops for iterative calculations and it does not allow one cell to alter the contents of another cell. These two features are typically needed in running mathematical models. Thus, the main objective of this study is to develop an Excel add-in, called BuildIt, that overcomes Excel's weaknesses. BuildIt overcomes some of Excel's weaknesses by: (1) providing a loop for repetitive calculations and (2) providing several operations (called actions) typically needed in building crop models. These actions include numerical integration, initialization of variables, and solving differential equations. BuildIt was written in Excel's script language, Visual Basic for Applications (VBA), but it does not require users to program in VBA to build their models. Users develop their models using BuildIt in essentially four steps: 1) write all the model formulas in the spreadsheet, 2) set up a loop for the repetitive calculations, 3) set up additional operations (such as numerical integrations, initialization of variables, and solving differential equations, as well as copying and manipulation of cell ranges), and 4) set up the model output (that is, to specify what to output from the model and where the model output should appear in the spreadsheet). In addition, BuildIt also supplies a feature called Trace that is able to visually depict spreadsheet cell dependencies so that modelers can visually see how the various variables and formulas are inter-connected to one another.

***Keywords***: excel, crop, agriculture, add-in

## INTRODUCTION

Most agriculturists receive very little to no formal training in computer programming. Consequently, they often struggle to translate their agriculture models into computer programs that can be correctly understood and executed by a computer. For them, computer programming often becomes a tedious and time-consuming drudgery that distracts them from their main purpose of study or work. This paper describes BuildIt, an Excel add-in that works within Microsoft Excel to enable the implementation of simple to large, complex models in Excel (Teh, 2011). Spreadsheet software, like Excel, provides a modeling platform that requires the least proficiency in computer programming. Unlike other modeling platforms that enforce a rigid programming structure, spreadsheets' unrestricted and open structure enable novices and non-programmers to easily implement their models in a spreadsheet and to have it run the model simulations. Nonetheless, Excel does have several key limitations that prevent the implementation of large, complex models. To circumvent these limitations, Excel's programming language, VBA (Visual Basic for Applications), could of course be used. However, using VBA requires programming skills that most agriculturists still lack. Moreover, requiring agriculturists to learn VBA would defeat the purpose of having an alternative and easier way for them to implement their models. To overcome Excel's limitations, an Excel add-in called BuildIt was developed. Although BuildIt was developed using VBA, it shields users from VBA. With BuildIt, users are able to implement simple to complex models in Excel without requiring knowledge in VBA or a strong proficiency in computer programming. BuildIt removes — or at least, greatly reduces — the distraction of computer programming and allows agriculturists to concentrate on the more important task of building their mathematical models and using them in their studies or work.

## METHODS

BuildIt overcomes some of Excel's weaknesses mainly by providing: 1) a loop for iterative calculations and 2) actions to perform certain specific tasks that are not possible or difficult to do in native Excel. A loop needs to be set up if a model requires the same set of calculations to be repeatedly performed. BuildIt requires three key information about the loop, which are: the loop counter, the interval size, and the loop criteria. The loop counter keeps track of the current loop cycle, while the interval size is how much the loop counter should be incremented at the end of every loop cycle, and the loop criteria are the conditions to which to end the loop.

BuildIt supplies 12 so-called actions, where each of these actions performs a specific task. Users will typically adhere to the following general steps in building their models in Excel: 1) implement all model calculations, 2) set up a loop for the repetitive calculations, 3) set up additional tasks needed such as numerical integrations, initialization of variables, and solving differential equations, as well as copying and manipulation of cell ranges, 4) set up the model output; that is to specify what to output from the model and where the model output should appear in the worksheet, and finally, 5) run the model. As an example, a generic crop growth model, called gcg (Teh, 2015 & 2006), was built to demonstrate the use of Excel (with the support from BuildIt) to build such mathematical models. However, due to the size of this model, only excerpts of this model are shown in this paper.

## FINDINGS AND DISCUSSION

The gcg model consists of five core model components: meteorology, photosynthesis, energy balance, soil water, and crop growth development. Figure 1 shows a portion of the calculations in the worksheet. Figure 2 shows the loop information required from BuildIt. This section instructs BuildIt to run daily simulations until the crop growth reaches the flowering stage. The simulation date is Jan. 1, 2000. Figure 3 shows the output section which instructs BuildIt to output the crop growth stage, the various plant part dry weights, plant height, rooting depth, leaf area index, and rooting zone water content. Figure 4 shows the output with charts drawn based on the model output in Figure 5.

| | F | G | H |
|---|---|---|---|
| 9 | | **RESPIRATION** | |
| 10 | | n1 | =RM*2^((Tmean-25)/10)*WGL/(WGL+WDL) |
| 11 | | $R'_M$ | =MIN(dayassim_c,H10) |
| 12 | | $\Lambda'_{canopy} - R'_M$ | =dayassim_c-RM_c |
| 13 | | $(\Lambda'_{canopy}-R'_M) / G_T$ | =IF(GT>0,H12/GT,0) |
| 14 | | | |
| 15 | | **LEAF DEATH** | |
| 16 | | $(2-\xi_s)$ | =2-dvs |
| 17 | | n2 | 0 |
| 18 | | n3 | =dvr/H16 |
| 19 | | n4 | =dvr/0.1 |
| 20 | | $\varepsilon_{age}$ | =IF(H16>=1,H17,IF(H16<=0.1,H19,H18)) |
| 21 | | n5 | 0 |
| 22 | | n6 | =0.03*MIN(1,(L-Lmax)/Lmax) |
| 23 | | $\varepsilon_{sh}$ | =IF(L<=Lmax,H21,H22) |
| 24 | | $\varepsilon_L$ | =MAX(eage,esh) |
| 25 | | | |
| 26 | | **LEAF AREA** | |
| 27 | | SLA | =interpolate(frac_dvs,frac_SLA,dvs) |
| 28 | | L | =WGL*SLA |

*Figure 1. Excel worksheet showing a small excerpt of the calculations in the gcg model. Equations are implemented using Excel formulas and functions*

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | **INPUT** | DATE(2000,1,1) | | current date | =B2+INT(_step) | |
| 2 | Date | | | day | =date-DATE(YEAR(date, 1, 0) | |
| 3 | | | | hour | | |
| 4 | **CONTROL** | | | | | |
| 5 | | | | | | |
| 6 | stepsize | 1 | | | | |
| 7 | step | | | | | |
| 8 | criteria | =dvs<=2 | | | | |
| 9 | | | | | | |

*Figure 2. Excel worksheet showing the loop information. This section instructs BuildIt to start crop growth simulations starting from Jan. 1, 2000 and to run the simulation until crop growth reaches stage 2 or the flowering stage (harvest)*

| | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **TO OUTPUT** | | | | | | | | | | | |
| 2 | **days** | $\xi_s$ | $W_{GL}$ | $W_{DL}$ | $W_S$ | $W_R$ | $W_O$ | h | $d_{root}$ | L | $\Theta_{v,root}$ | |
| 3 | =date-Control!B2 | =dvs | =WGL | =WDL | =WS | =WR | =WO | =h | =droot=L | | =Water!E12 | |
| 4 | | FALSE | FALSE | FALSE | FALSE | FALSE | FALSE | FALSE | FALSE | FALSE | FALSE | |
| 5 | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | |
| 7 | **OUTPUT** | | | | | | | | | | | |
| 8 | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | |

*Figure 3. Excel worksheet showing the list of parameters to be included in the model output: the growth development stage ($\xi s$), the dry weights for green leaves (WGL), dead leaves (WDL), stem (WS), roots (WR), and storage organs (WO), plant height (h), rooting depth ($d_{root}$), leaf area index (L), and the rooting zone soil water content ($\Theta_{v,root}$)*

| | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | TO OUTPUT | | | | | | | | | | | |
| 2 | days | ξs | WGL | WDL | WS | WR | WO | h | $d_{root}$ | L | $\Theta_{v,root}$ | |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.4 | 0.6 | 0 | 0.01 | |
| 4 | | FALSE | FALSE | FALSE | FALSE | FALSE | FALSE | FALSE | FALSE | FALSE | FALSE | |
| 5 | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | |
| 7 | OUTPUT | | | | | | | | | | | |
| 8 | 0 | 0.1 | 1.44 | 0 | 0.29 | 0.16 | 0 | 0.04 | 0.04 | 0.04896 | 0.2 | |
| 9 | 1 | 0.125 | 1.864 | 0 | 0.397 | 0.222 | 0 | 0.049 | 0.052 | 0.06293 | 0.254 | |
| 10 | 2 | 0.149 | 2.31 | 0 | 0.515 | 0.291 | 0 | 0.059 | 0.064 | 0.07742 | 0.272 | |
| 11 | 3 | 0.173 | 2.94 | 0 | 0.692 | 0.393 | 0 | 0.07 | 0.078 | 0.0978 | 0.284 | |
| 12 | 4 | 0.197 | 3.588 | 0 | 0.884 | 0.503 | 0 | 0.084 | 0.088 | 0.11849 | 0.267 | |
| 13 | 5 | 0.221 | 4.406 | 0 | 1.139 | 0.649 | 0 | 0.098 | 0.1 | 0.14401 | 0.29 | |
| 73 | 65 | 1.793 | 54.45 | 172.9 | 264 | 68.69 | 136.1 | 0.4 | 0.496 | 0.6908 | 0.269 | |
| 74 | 66 | 1.823 | 46.98 | 180.8 | 264.8 | 68.94 | 141.8 | 0.4 | 0.496 | 0.57786 | 0.262 | |
| 75 | 67 | 1.854 | 39.18 | 188.9 | 265.4 | 69.14 | 147.2 | 0.4 | 0.496 | 0.46637 | 0.256 | |
| 76 | 68 | 1.883 | 31.48 | 196.8 | 265.8 | 69.28 | 152.1 | 0.4 | 0.496 | 0.36256 | 0.25 | |
| 77 | 69 | 1.913 | 23.55 | 204.9 | 266.1 | 69.37 | 155.9 | 0.4 | 0.496 | 0.26207 | 0.245 | |
| 78 | 70 | 1.943 | 16.61 | 211.9 | 266.2 | 69.41 | 158.7 | 0.4 | 0.496 | 0.17842 | 0.3 | |
| 79 | 71 | 1.973 | 11.71 | 216.8 | 266.3 | 69.43 | 161.1 | 0.4 | 0.496 | 0.12122 | 0.282 | |
| 80 | | | | | | | | | | | | |

*Figure 4. The model output which starts from row 8 until 72*

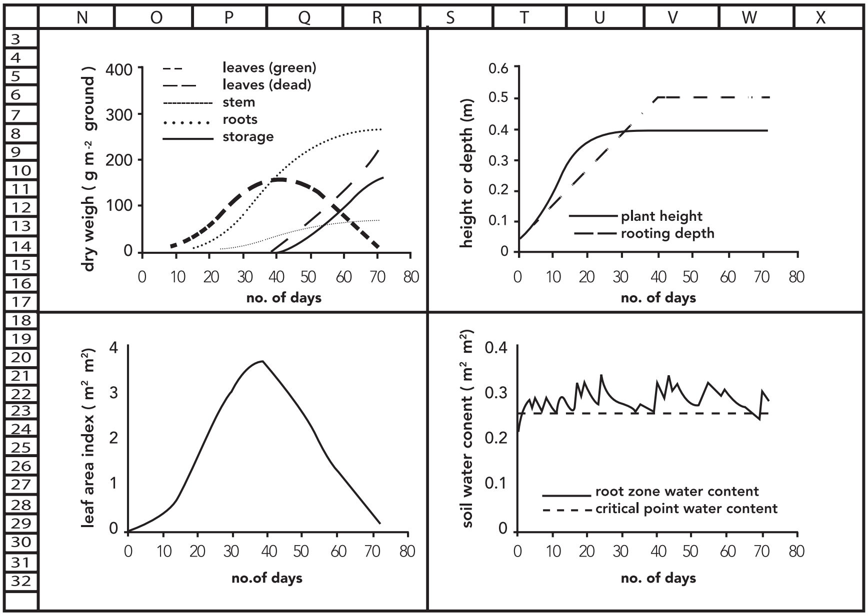


*Figure 5. Charts are drawn from the model output to show the change in selected growth parameters and the soil water content*

## CONCLUSION

BuildIt overcomes certain limitations in Excel, enabling mathematical models to be easily implemented in Excel without requiring agriculturists to learn a computer programming language or be proficient in computer programming. With BuildIt, agriculturists can focus more on their modeling work and be less distracted by computer coding.

## BENEFIT FOR HIGHER EDUCATION

The main benefit of using BuildIt is in allowing agriculture students to develop and build their models in Excel without the distraction and drudgery of having to learn computer programming.

## REFERENCE

Teh, C. B. S. (2011). Overcoming Microsoft Excel's weaknesses for crop model building and simulations. *Journal of Natural Resources and Life Sciences Education*, *40*, 122-136.

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